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ABSTRACT

The main purpose of this symposium was to find new ideas and resources for the evaluation and improvement of physics education on all levels. The papers included in this document are entitled: (1) "Quality of Physics Teaching Through Building Models and Advancing Research Skills"; (2) "Evaluation of Physics Education in Terms of Its Long Term Effects"; (3) "The Physical-Mathematical Classes and Summer School on Physics at Moscow Institute of Physics and Technology"; (4) "Evaluation and Qualification of Physics Education: Reform in Danish Secondary Schools"; (5) "Aims and Goals of Physics Teaching on Personal Level"; (6) Physics Teacher Evaluation by Students: A Report on 10 Years of Experience at the University of Innsbruck"; (7) "Problem Solving as a Probe for Examining the Epistemological Obstacles in the Understanding of Physics"; (8) "Coupling of Physical Situation to Graphical Representation"; (9) "Use of Stroboscopic and Videocamera in Studying Two-Dimensional Motion"; (10) "Electricity Concepts in Primary School"; (11) "On the Integrality of Orbital Angular Momentum Quantum Numbers"; (12) "On the Teaching of the Concept of Energy at the Upper Secondary School"; (13) "An Analysis of Exercises in Finnish Secondary School Physics Textbooks"; (14) "The Microcomputer in the Laboratory: Contributions to Conceptual Development"; (15) "New Computer Demonstrations in Physics Teaching"; (16) "Satellites in Education and Training in Europe and North America"; (17) "The Minerva Project and the Teaching of Physics"; (18) "Empirica--A Program for Data Acquisition and Analysis in Science Teaching and Its

Pedagogical Applications"; (19) "Three Computer Programs for Junior High School"; (20) "The Application of Physics in Teaching Oral Radiology"; (21) Physics and Technology of a Solar Car"; (22) "An Integrative Course as a Possibility of Developing Physics Teaching"; (23) "Aspects on Interdisciplinary Physics Teaching"; (24) "Difficulties in Physics Teaching"; (25) "Modern Physics Pieces of Information in Teaching Process--The Integration of Mathematic and Natural-Scientific Education in Czechoslovakia"; (26) "Problems of Teaching Physics in Estonian Universities"; (27) "Alternative Ideas in Mechanics: Where Can They Come From?"; and (28) "Cognitive Style of Students as an Essential Factor of Forming Their Physical World Conception." (KR)

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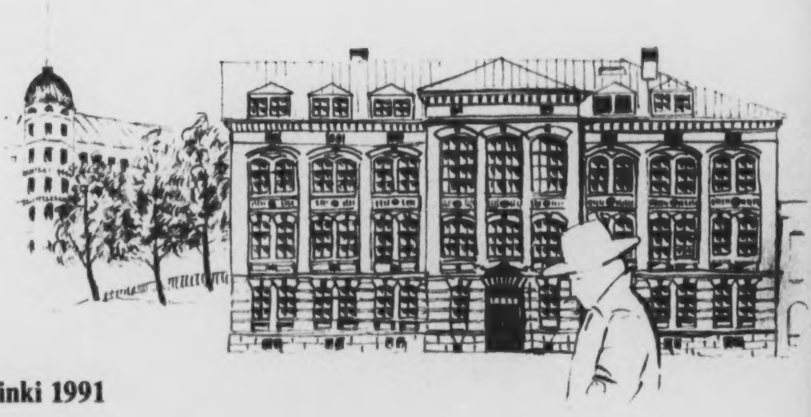
RESEARCH REPORT 96

Department of Teacher Education
University of Helsinki

Maija Ahtee – Veijo Meisalo – Heimo Saarikko (Eds.)

Proceedings of the
INTERNATIONAL SYMPOSIUM ON THE EVALUATION OF PHYSICS EDUCATION
CRITERIA, METHODS AND IMPLICATIONS



Helsinki 1991

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RESEARCH REPORT 96

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Proceedings of the
INTERNATIONAL SYMPOSIUM ON THE EVALUATION OF PHYSICS EDUCATION

CRITERIA, METHODS AND IMPLICATIONS

Helsinki 1991

Proceedings of the

INTERNATIONAL SYMPOSIUM ON THE EVALUATION OF PHYSICS EDUCATION

CRITERIA, METHODS AND IMPLICATIONS

Helsinki, June 25 – 29, 1990

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TO THE READER

The International Symposium on the Evaluation of Physics Education (ISEPE) with the subtitle Criteria, Methods and Implications was held in Helsinki June 25 – 29, 1990. The main purpose of the Symposium was to find new ideas and resources for the evaluation and improvement of physics education on all levels. It was also intended to give a forum for the exchange of information on research and development projects related to physics education, and reports of interesting results.

The organizing effort was divided by several Departments of the University of Helsinki and the Finnish Physical Society, but the main responsibility has been at the Department of High Energy Physics and the Department of Teacher Education. Financial assistance of the Finnish Ministry of Education made it possible to arrange the conference and have the invited speakers by us. The Local Organizing Committee was selected from the staff members of the University Departments contributing to the organization of ISEPE. The Programme Committee had members from different Finnish universities. The International Advisory Committee was originally thought to be strictly European, but also John W. Layman from University of Maryland was elected as a member. The organizers appreciate greatly the contribution of the International Advisory Committee.

The organizers wish to thank the 350th Anniversary Committee of the University, the European Physics Association and the Finnish Physical Association, as well as the Economic Information Bureau for valuable support. The organizers are also grateful to different Departments of the University and their staff for vital assistance.

There were also problems in the arrangement of ISEPE. The worst one was perhaps the political situation in eastern Europe and especially the critical times in the German Democratic Republic of those days. An unusually large number of preregistered participants had to inform at the very last moment, that they are unable to attend the Symposium. This caused much extra work and improvisation especially to the Programme Committee, but we hope that the final result was satisfactory to all participants.

The Editors of these Proceedings regret very much, that there has been a delay in the printing process. This is due in part to waiting some manuscripts in their final form. Partly we have had troubles with the workload of the technical editors at the Department of Teacher Education, and the current critical financial situation. Nevertheless, we hope that the final result is useful to the participants and other colleagues working to the advancement of physics teaching on various fields.

3

QUALITY OF PHYSICS TEACHING THROUGH BUILDING MODELS AND ADVANCING RESEARCH SKILLS

Charles W. Misner

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New technology centering on personal computers changes the scope of subject matter that can be taught at introductory levels. This poses a challenge of designing a new curriculum that teaches the content and the skills that will be most useful. At the University of Maryland a group of primarily research physicists has explored such changes in several ways. I will emphasize the approaches that seem appropriate for modification to fit science teaching at the high school/gymnasium and middle school levels. The specific technology that is central here is the electronic spreadsheet, but only for the reason that it has proved so intuitive and readily grasped by non-programmers. The essential change is to give students at a very early stage the ability to manipulate numbers wholesale, and view them as graphs (rather than as tables, or, as at present, as individual numbers).

This lecture will begin with some examples that illustrate the ease with which scientific calculations can be done using a spreadsheet. Next is a description of some of the ways we have used spreadsheets in teaching introductory calculus-based physics at the first year level in an American university. Then I speculate on the changes that would be desireable in secondary education if the personal computer were there to become the commonplace desktop tool that it has already become in business and commerce in many countries. Finally I try to identify what general features the suggested approaches emphasize.

Spreadsheets. It is unlikely that a reader can appreciate the simplicity in use of an electronic spreadsheet without having seen an actual demonstration, or having spent a afternoon learning to use one. Some examples are given in references [1] and [2] that will not be repeated in this written report. However we adduce some indirect evidence for the simplicity of spreadsheets—millions are in use. It is generally thought that spreadsheets, first VisiCalc, then Lotus 1-2-3, were responsible for the adoption of personal computers by the business community. When this occurred, only dedicated word processors (which ran a single program bundled with the hardware) were common in state-of-the-art offices. The current ubiquity of personal computers running word processing programs occurred only after these machines appeared in the business world to run spreadsheets.

The primary advantage of a spreadsheet as a computational tool is its pencil and paper metaphor. It appears to do nothing differently than it would be done on paper (the old fashioned bookkeeper's worksheet) but I like to say that it provides an "invisible assistant" who does the repetitive work and the graphing. Thus repetitive calculations have only to be done once, and the "assistant" can then repeat them several hundred times if desired. A related effect is that the computer does the programming as you calculate—this means that after you have done a calculation in the paper and pencil style (perhaps with some help on iterations), the computer is programmed to repeat similar calculations with different data.

Another aspect of the pencil and paper metaphor is that all intermediate steps in a calculation are displayed, or virtually displayed. That is, every formula appears on the screen as a number (the result of evalulating the formula). For the unsophisticated user or young student this gives the computations a concreteness that contrasts strongly with the abstraction needed to write programs in conventional languages such as BASIC or Pascal. Arrays appear as long lists of numbers, and computed functions as parallel columns of numbers. Although these numbers do not all appear simultaneously on the screen, the screen can be panned over the virtual sheet of paper to show any screenful from these masses of numbers. Students don't, of course, look at many numbers, but the fear of a computer as a mysterious "black box" disappears when every number that it is calculating is made accessible in this way.

Since this electronic worksheet accepts text as well as numbers and formulas, students can be taught to present their work in effective reports at the same time that they are being taught how to use the computing engine to solve physics problems. They will also, no doubt, be aware that the spreadsheet has many uses outside of physics, so that the computing skills they acquire in their science classes will be worth remembering against the day they are employed in some other office environment.

University Mechanics. The decisive aspect of our use of computers in introductory physics is that the computer becomes a tool in the hands of the student. We try to provide an introduction to research uses of computers in physics. (This is described in connection with tools for using the Pascal language in introductory physics in [3]. A text supplement [4] providing spreadsheet support for introductory physics should appear soon.) In spreadsheet based courses the student begins each computer assignment during the first several weeks with either a blank worksheet, or one he/she wrote in a previous assignment. Only after some procedures become familiar do we provide prewritten "templates" that leave only the new physics to be inserted by the student.

Our aim in this development is to have the *student* build models of physical systems by writing programs (worksheets) that incorporate physical principles. The student must then test these models for their content by exploring the graphs drawn by the program under a variety of conditions. The student should also test these models for applicability by comparing (at least qualitatively) these graphed behaviors with the motions of real mechanisms in lab or demonstrations.

One advantage of the computer program approach is that the student's conceptual model of some physical system is, as a computer program, more visible to the instructor. It is also more visible to the student, and is a more suitable target for student attention than is the single number "answer" to conventional exercises by which instructors previously tried to test whether a valid conceptual model was resident within a student's brain.

My principle experience with student use of computers in introductory physics is in the mechanics portion of the course. There it offers several advantages. The first is that the fundamental Newtonian law $a = F/m$ (in the form of the pair $dv = (F/m)\,dt$ and $dx = v\,dt$) plays a significant role in all examples, and is not ignored in favor of "practical" formulae like $v^2 = 2as$ or $x = A\cos\omega t$ which will mostly be misapplied and then forgotten. This emphasis on Newton's laws at least gives students some chance to see the unity and breadth of fundamental physics which researchers find so appealing. Another advantage is that, with computers, students learn to communicate using graphs. Graphs are easily prepared so they become the normal means by which the student displays results from homework exercises to the grader. A third advantage is that a computer model lends itself naturally to exploration. Professional physicists are eager to glance at graphs reflecting a varied set of initial conditions or other parameters that can be changed every few dozen seconds. To students such exploration is not natural, but with repeated provocation they can be taught that a model must act out its possibilities to serve its purpose. Without questions and other pressure they may write a program and not realize that they can explore its consequences (or even do basic debugging).

Some teachers worry that if students were to learn computer methods for solving physics problems first, they might not work hard on analytical methods. This is mistaken. Computer use motivates interest in a wider variety of analytical skills than we are accustomed to teach. Analytic solutions are needed for debugging, and the significance of their parameters is well appreciated there. In addition dimensional analysis becomes important. A formula can usually accept or yield a number of any size, but a numerical integration may not. Choosing a "small" integration step Δt is very different in a Bohr orbit or a planetary orbit, and dimensional analysis usually provides the only practical guide for one's first attempts. Approximations can also be naturally introduced. Is an "exact" solution to an oversimplified (i.e., approximate) equation better than an approximate (numerical) solution of a more realistic equation?

Secondary Education. Spreadsheets are a commercial success and enjoy widespread use in business and commerce by employees and managers who have generally not learned much mathematics nor computer science at the university level. From this, and some direct evidence, one believes that spreadsheet skills are accessible to secondary education students, which opens the possibility of experimental attempts to try a dramatically different approach to abstract mathematics (algebra and calculus). Because a spreadsheet has the appearance of merely simplifying the arithmetic manipulation of numbers in wholesale quantities, it allows one in effect to use differential equations prior to learning algebra and calculus. This would allow mathematics to follow the example of language where a great deal of use and many examples precede the introduction of abstract descriptors ("noun", "sentence", "phrase", "preposition", etc).

The proposal then is that in many subjects—mathematics, economics, biology, chemistry, physics—pupils be introduced to areas where the description and management of change is important. Students could construct computer models of describable change (determinate or random) as soon as numerical measures of the relevant factors, and graphical presentation of their relationships, could be made meaningful. If this is possible at an early enough stage, it could be that the discussion of such spreadsheet models would motivate even the basic algebraic step of using a symbol to designate a variable. Thus the variable P refers to the population column in some worksheet, and an instance of it can be found in any row, etc. If there is something worth talking about on the graphs, even young students may not want all descriptions of their construction to be carried on in the limited vocabulary of "I multiplied the number is this column by the number in this (other) column and then ... ." The new symbolic language should be more acceptable after a need for it has been experienced.

Quantitative science may be more attractive to young people when introduced through the use (numerical solution) of differential equations. In this form it has many similarities to popular computer games. The dynamics in science is just Hellenistic english for the action, motion, and change that are so prominent in many games. The active formulae of quantitative science, which students must embed in the programs they write, are just the rules of the game they are asked to play. In many examples from radioactivity to genetics chance will also enter (as in games) through the use of probabilities and random number generators. This combination of action, rules, and chance could be much more fun than the usual apples and areas by which algebra and calculus are traditionally introduced. Even Newton could not teach himself calculus until after he visualized a dynamic application that we later called a differential equation.

References:

[1] C. W. Misner, Spreadsheets for Physicists, *Computers in Physics*, May-June 1988, pp. 37–41.

[2] C. W. Misner, Spreadsheets in Research and Instruction, *in* E. F. Redish and J. S. Risley, editors, *Proceedings of the Conference on Computers in Physics Instruction* (Addison-Wesley Pub. Co., Reading, Mass., 1990) pp. 382–398.

[3] Wm. M. MacDonald, E. F. Redish, and J. M. Wilson, The M.U.P.P.E.T. Manifesto, *Computers in Physics*, July-Aug 1988, pp. 23-30.

[4] C. W. Misner and P. J. Cooney, *Spreadsheet Physics* (Addison-Wesley Pub. Co., Reading, Mass., to be published).

EVALUATION OF PHYSICS EDUCATION IN TERMS OF ITS LONG TERM EFFECTS

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Abstract

Most evaluation studies are concerned with the immediate or at most moderately delayed effects of previous instruction on the learner. However a study was conducted at the IPN by Lore Hoffmann, Jürgen Rost and myself which was concerned with long term effects. It surveyed the level of physics education among adults who had left school between zero and 20 years prior to the assessment, and their respective educational careers with regard to physics. This cross-sectional design enabled us to calculate correlations between the achieved level of physics education (criterion variables) and variables of the "physics instruction" career (predictor variables) revealing elements of instruction that have in the long run proved positively influential, ineffective or counterproductive.

The specification of the physics education variables was based on a curricular Delphi study, an inquiry investigating the type of physics education which is desirable in an industrial society like ours. It revealed that desirable, pedagogically meaningful physics education should not be restricted to knowledge and comprehension of physical concepts, but rather should comprise the development of certain attitudes, interests and behaviour with respect to physics and technologies based on physics. The decision as to which variables of individual educational careers to include was taken pragmatically. We included mainly those predictors which (1) had proved their effectiveness in other studies, (2) were still accessible in the memories of those questioned, and (3) could be influenced by pedagogical measures.

A total of 869 adults participated in the study. For methodological reasons the domain of physics was restricted to the areas of "Energy and energy supply" and "Electricity and domestic electrical appliances". The results indicate that effects of physics instruction are in evidence long after the school career has ended. This applies particularly to the area of knowledge, whereas the influence on attitudes, interests and behaviour is relatively low.

1. The variables investigated

1.1. The variables for operationalization of physics education

The results of a curricular Delphi study on physics education /1/ were used to operationalize the criterion variables. In the first two rounds of the study, the 70 or so participants (selected according to certain educational criteria) formulated statements on physics education which were to include the following elements:

o Situations, contexts or motives in or for which education in physics is meaningful today and will remain so in the immediate future;

o Areas of physics which are considered to have significance in conjunction with the situations, contexts or motives named in fulfilment of the preceding condition;

o The appropriate or desirable modality of an individual's disposition over, or of his or her dealing with physics.

This procedure yielded approx. 500 statements. By means of cluster analysis these statements could then be assigned to "bundles", each of which could be interpreted as a different concept of physics education (cf. Table 1).

In the third round of the study the participants were asked to describe in detailed form the knowledge, attitudes, interests and behaviour adults should have developed with relation to "Energy and energy supply" and "Electricity and domestic electrical appliances", two thematic areas considered to be particularly relevant in the first two rounds. This material was then used to develop a questionnaire on physics education containing the subtests summarized in Table 1.

1.2. The variables for operationalization of educational career

In establishing the educational career variables (predictor variables), from which the effects on the level of education can be inferred and which can be used to set up pre-experimental hypotheses on these effects, we drew mainly on other empirical studies with comparable goals. In addition we referred to the results of the curricular Delphi study /1/ on the characterization of the type of physics learning possible in schools. This yielded the variables shown in Table 2, which were converted into corresponding questionnaire items.

Table 1: Outline of the criterion variables

Concept of physics education	Corresponding subtests in the questionnaire for the areas energy and electricity*
A: Socio-political action with awareness of one's responsibility, and knowedegable public discussion of physics-based technologies	o Attitude toward alternative energy technologies o Faith in progress in connection with the energy supply o Attitude to energy saving o Energy saving behaviour o Active commitment to energy saving o Receptive commitment to energy saving
B: Mastery and understanding of technical appliances, instruments and systems encountered in every day life	o Handling of electrical appliances
C: Enhancement of the individual's emotional experience of nature and technology	o Academic interest in dealing with electricity o Practical interest in dealing with electricity
D: Dealing with physics in a way that furthers personal intellectual development	o Theoretical knowledge in the areas of energy and electricity o Practical knowledge in the areas of energy and electricity

* The subtest structure represented in the table was developed partly in the course of data analysis. Some subtests, for example, proved not to be one-dimensional and had to be split in accordance with the determined factor structure. The differentiation of knowledge (theoretical and practical) is also due to the results of factor analysis.

Table 2: Outline of the predictor variables

- Time elapsed since last physics instruction (number of years between last period of physics instruction and time of study)

- Quantity of physics instruction
  - Number of weekly physics periods from the age of 12 onwards
  - Out-of-school occupation with energy and/or electricity

- Type of physics learning possible in school
  - Type of school attended
  - Orientation of instruction to a certain concept of physics education. Factor analysis yielded the following concepts:
    - Understanding and discovering laws of physics (instruction in line with this concept emphasizes how concepts and laws of physics are ascertained and communicated)
    - Treatment of physics for society/everyday life (here physics is presented with reference to its significance for society using examples from everyday life, though without requirement of practical experience with equipment and without building up competence to act)
    - Practical treatment of physics guided by interest (this concept of physics instruction enables direct practical experience to be gained with technical equipment and encourages the development of the learners' own interests)

- Motivating factors
  - Stimulating factors outside school (e.g. toys, parents, media)
  - Interest in the school subject physics in relation to interest in other school subjects
  - Activation in physics instruction (boring, optimal, over-activated)

- Sex

2. The study method

The educational career variables cannot by their very nature be influenced, but can only be investigated post facto and checked in their variation by the design of the sample. The aim of the sampling was to obtain sufficient variance in the educational career variables and to examine a representative section of the 20 to 40-year-old age group. To this end a random sample was taken.

A questionnaire was developed for data collection, which comprised the variables listed in Table 1 and 2. A total of 869 persons (417 women and 452 men) between the ages of 20 and 40 were asked to complete the questionnaire. They had been randomly selected by means of a standardized procedure from the telephone directories of 11 towns throughout the Federal Republic of Germany. The resulting sample is not, however, representative for the whole population of 20 to 40-year-olds. Those with higher school leaving certificates are over-represented.

Completion of the questionnaire required an average of two hours. This generally took place in the subject's home in the presence of an interviewer (psychology student at an advanced stage of his/her course). The completed questionnaires were then scored by other students (professorial assistants) using a written key. Scoring consensus of 98% was achieved.

Multivariate regression analysis was then applied to the scorings of the criterion (Table 1) and predictor (Table 2) variables, whereby each criterion variable was attributed to precisely those predictor variables which were, according to a certain pre-experimental hypothesis, possible elements of influence. In addition to this hypothesis-guided examination, overall analyses were conducted, in which all predictor variables were inserted in the regression equation in order to judge the strength of their influence (in comparison with all other variables) more appropriately.

3. Results

The large number of variables (15 predictor and 11 criterion variables) meant that the study yielded a great many detailed results which cannot all be presented here. (For detailed documentation see /2/).

Table 3 gives an outline of the relationships ascertained between the physics education variables (rows) and the educational career variables they are to explain (columns). Further explanation of individual variables is given in the following sections. The matrix elements are the ß-weights, (multiplied by 100 and significant at the 5% level) of the regression of a single criterion variable to all predictor variables taking the whole population as a basis. They are a measure of the strength of this relationship. Subsamples separated according to sex yielded different values in women and men for a few ß-weights.

Table 3 can be read in rows or columns. Read in rows it provides information on the way in which each criterion variable relates to the predictor variables included in the investigation. The first 15 columns show the beta regression coefficients of the individual predictors (the black areas are proportional to these ß-weights), while the final column shows the total explained inter-individual variance of the criterion variable (100% would mean that the criterion variable can be attributed totally to the predictors).

The percentage of variance accounted for differs greatly for the individual criterion variables. At most it is 50%, for the variable "Handling of electrical appliances". A glance at the ß-weights, however, shows that it is almost exclusively connected with the variable "Sex". If this predictor is excluded from regression, the multiple R^2 falls to 15%.

		Quantity				Type of learning experience				Motivating factors							
		End of physics instruction	Total no. weekly periods	Dealing with electr. outside school	Dealing with energy outside school	Treatment of physics for soc./everyday life	Pract. treatment of phys. guided by interest	Underst. and disc. laws of physics	Type of school	Childhood toys	Parental stimulus	Peer stimulus	Media	Particular experience	Interest in the school subject physics	Sex	← Explained variance in %
Attitudes	Attitude towards alternative energy technologies	11			12		-16	13	9						-12		14
	Faith in progress	-14		8	-13		14	-11								12	12
	Attitude to energy saving				7	-10	-9	11									5
Interest	Academic interest in dealing with electricity			10	13			13		10			10	9		9	15
	Practical interest in dealing with electricity	10		13				10	-11	19				10	18		20
Behaviour	Energy saving behaviour	-10			9				10						-9	-9	5
	Active commitment to energy saving			-8	17	-10	-11	19	11								13
	Receptive commitment to energy saving	-8			17	-8		9					14			9	11
	Handling of electrical appliances			9						10					9	[illegible]	50
Knowledge	Practical knowledge		12	13				11	11	10					21	[illegible]	43
	Theoretical knowledge	9	12		12	-8	-7	20	[illegible]				10		14	[illegible]	40
	Strength of effect in % →	11	19	11	9	7	7	18	24	14	3	(2)	9	5	24	51	

Table 3: Table of connections revealed between the variables of educational level (rows) and the variables of educational career designed to explain them (columns). The figures inside the matrix are the β coefficients, multiplied by 100, of the corresponding regression analyses

A relatively high variance percentage can also be ascertained for the knowledge variables: 43% for practical knowledge and 40% for theoretical knowledge.

For the remaining variables our predictors proved less effective. The variables "Attitude to energy saving" and "Energy saving behaviour", each a 5%, have the lowest explained variance. The positive attitude to energy saving ascertained, and behaviour largely consistent with this attitude appear to have become to a considerable extent common features independent of special school factors.

If Table 3 is read in columns, the figures in the first 11 rows can be interpreted as strengths of effect of a certain predictor on the individual variables of educational level, and the last row (multiple R^2) as the global strength of effect on physics education, as operationalized with our 11 criterion variables.

The various predictors differ considerably in their global strength of effect. The variable "Sex" has the largest (51%), followed by the variables "Interest in the school subject physics during time at school" (24%), "Type of school" (24%) and "Total number of weekly physics periods" (19%). The lowest strength was ascertained for a few motivating factors. Peer or parental stimulus, for example, obviously played a lesser role in the development of a person's physics education. It can be presumed, however, that mainly unconscious processes not covered by the study take effect here, which means that the actual influence (and not only the perceived influence associated with concrete events) was systematically underestimated.

3.1. Results in the area "Knowledge"

The physics knowledge of the 869 subjects was ascertained for the areas Electricity/electrical appliances and Energy/energy supply. Factor analysis of the 24 knowledge items showed that 13 (mainly electricity) items could be assigned to the factor "Practical knowledge" and 11 (mainly energy) items to the factor "Theoretical knowledge".

The following picture was obtained for the origin of the knowledge or, more exactly, to which in-school and out-of-school variables the practical and theoretical knowledge operationalized in the subtests can be related (cf. the final two rows of Table 3):

- o Soon after a person leaves school, her/his knowledge stabilizes: it is lower than during the years in school, but - contrary to popular opinion - not everything is forgotten. The difference between a person who last had physics instruction only a short while back and a person who left school 20 years ago is (despite its close association with school in our test) barely a quarter standard deviation for theoretical knowledge, and for practical knowledge, with its clear links with everyday life, even less (the corresponding ß-weight is not significant).

o Those who receive more physics instruction at school have greater practical or theoretical knowledge as adults. Once gained, the advantage remains throughout their lives. The fact that in both cases ß = .12 indicates that physics instruction also has a positive influence on thematic areas which it did not explicitly include.

o Dealing with a certain area of physics outside school has a considerable influence on the knowledge in this area (ß = .12; .13). There is also evidence that the media influence theoretical knowledge, and childhood toys practical knowledge (in both cases ß = .10).

o Theoretical knowledge depends relatively strongly on the type of school attended (ß = .27). Even if all other influences which accompany attendance of a higher secondary school (*Gymnasium*) are taken into account, a person who attended this type of school has, with a standard deviation of approx. one third, greater theoretical knowledge than a person who attended an intermediate secondary school (*Realschule*). About the same difference can be observed in turn between the latter and those who attended secondary modern schools (*Hauptschule*). For practical knowledge the differences, though smaller, tend in the same direction (ß = .11).

o Instruction devoted primarily to the concept of "Understanding and discovering laws of physics" has a particularly favourable effect on theoretical knowledge (ß = .20).

o Those who took more interest in physics instruction while at school retain a greater store of physics knowledge in later life. It is not true, however, that greater interest led to more effective physics instruction. (If this were the case the data would have revealed an interrelation between interest and the quantity of physics instruction.) Yet our data indicate a certain continuity of interest, which causes physics knowledge to be kept up to date outside school). This interpretation is further supported by the fact that for practical knowledge ß = .24, whereas for theoretical knowledge ß = .14 only.

o Men have considerably greater practical knowledge than women (ß = .34). For theoretical knowledge the difference is not so extreme (ß = .21).

3.2. Results in the area "Attitudes"

The study obtained data on attitudes to the following (cf. the first 3 rows of Table 3):

(a) Attitude to alternative energy supply technologies in comparison with nuclear technology:

Here the data indicated a mean positive attitude to alternative technologies and a mean negative attitude to nuclear technology. For example, the statement

"Much more than at present must be invested in the development of alternative energy technologies (utilizing wind, sun, tides, waste incineration)" was accepted by 93%, and the statement

"Improved technology will, in the future, enable the risks still attached to nuclear power to be eliminated"

was rejected by 68%.

(b) Attitude to energy saving:

On this scale, too, a high mean level of agreement was reached. Thus the statement

"We should in future do without luxury goods which entail high energy costs in production"

was accepted by 79%.

(c) The attitude that there will always be new energy sources for exploitation (faith in progress):

Here a mean level of agreement was achieved. For example, the statement

"Technicians/engineers and physicists will solve the problems caused by increased energy requirements"

was rejected by approx. 50%.

In contrast to the area of "Knowledge" it was not possible to ascertain the "origin" of the attitudes to any significant degree. There is, for example, no connection between a person's knowledge of energy and the three attitude scales shown above. It can be seen that the influence of school in this area is on the whole low, as there is no connection with the quantity of physics instruction.

With regard to the school variables, the type of instruction concept applied appears to have a certain influence on the formation of attitude. Rather surprisingly it is the concept "Understanding and discovering laws of physics" which accompanies positive attitudes to alternative energy technologies (.13) and energy saving (.11), with little faith in progress (-.11). Both other concepts have in contrast more of a counter-productive influence. There are various possible explanations for this surprising phenomenon. It could, for example, be an artefact resulting from the method of obtaining data. People who have a particularly positive attitude to energy saving and to alternative energy technologies could judge the physics instruction they once received as deficient in this specific area, an explanation which would produce precisely the correlation observed. On the other hand, it could be a real effect of these instruction concepts. It would be feasible, for instance, that instruction which excludes, contrary perhaps to student preference, all reference to society, provokes strong commitment to social policy. Contradictory processes of this kind in attitude formation have frequently been described in sociopsychological literature. It is also possible for instruction in keeping with the concept "Practical treatment of physics guided by interest" to foster a disinclination towards criticism of technology with its demands of saving energy, of developing and applying alternative energy technologies.

On no account should it be concluded from these results that no positive effects can be expected from a practical approach to physics or reference to society. It should rather be assumed that instruction which relates practical activity to the development of conceptuality and which does not simply verbalize the social significance of physics but also develops competence to act can very probably have beneficial effects. In this study, however, sufficient differentiation could not be achieved for these aspects.

Among the out-of-school variables it is primarily the age of the person and his/her dealings with energy issues which are connected with attitudes. Younger people (who finished physics instruction much more recently) and those who deal with energy issues outside physics instruction have as a rule a positive attitude to alternative energy and have less faith in progress.

3.3. Results in the area "Interests"

The interest of adults in dealing with physics was measured on two scales: a practically oriented interest (making things, taking things apart) and an academically oriented interest (reading, visiting museums, etc.).

Both directions of interest were closely connected with a person's knowledge level. Interest cannot, however, be attributed to variables of educational career to the same extent as was possible for the area of knowledge. The following correlations were obtained:

o Interest does not depend on the quantity of physics instruction.

o The instruction concept "Understanding and discovering laws of physics" has a positive influence on interest.

o The type of school is insignificant for the development of academic interest. Former secondary modern students (Hauptschüler), however, have a greater practical interest than those who formerly attended a higher secondary school (.11).

- A certain continuity exists between current interest in dealing with physics and former interest when at school or former use of technical toys.

3.4. Results in the area "Behaviour"

The following variables were investigated for the area of behaviour:

(a) Energy saving behaviour
The frequency of certain behaviour types whereby energy is saved was investigated.
Example: Waiting until there is enough washing to fill the washing machine (39% always, 43% almost always, 4% sometimes, 1% seldom, 13% no opportunity).

(b) Active commitment to energy saving
Example: I have at some stage demonstrated against a particular energy policy or a particular building project (24% agreement).

(c) Receptive commitment to energy saving
Example: There are issues of public energy supply on which I inform myself in detail (51% agreement).

(d) Handling of electrical appliances
Example: Installing a light fixture in house/flat (72% had done this).

Connections found with other variables of the level of education were as follows:

- Active energy saving commitment and energy saving behaviour have a relatively close connection with positive attitudes to alternative energy technologies. For receptive commitment there is hardly any correlation.

- Frequent handling of electrical appliances corresponds to a large store of practical knowledge and, slightly less distinctly, to practically or academically oriented interest. The data indicate that the handling of electrical equipment is a direct source of knowledge increase.

There is, in contrast, no distinct correlation with the independent variables, if the clear sex-specific mean differences for the variable "Handling electrical appliances" are excluded.

The results in detail are as follows:

o The quantity of physics education has no influence on energy saving commitment or on the handling of electrical equipment. Those who deal with energy issues outside school do, however, have a greater commitment to energy saving (ß = .17).

o The influence of various instruction concepts is in the case of energy saving commitment quite similar to their influence on attitude formation (cf. section 4.3). A further interesting feature is that the concept of "Practical treatment of physics guided by interest" has no effect on the "Handling of electrical appliances".

o The influence of the media on receptive energy saving commitment is limited (ß = .14). There is no evidence of increased active commitment.

o Men handle electrical equipment far more frequently than women (ß = .60). This cannot be cpmpletely accounted for by the lesser practical knowledge of the women. Former secondary modern students are the female group most affected.

4. Some conclusions

The results listed in section 3 and the findings summarized in /2/ indicate that physics instruction as practised in our schools does have a long term effect. For further development of instruction major efforts should therefore be concentrated on reinforcing the elements with positive influence and avoiding those which have proved ineffective or counter-productive. The following paragraphs comment on this with special reference to the following:

(1) Didactic concept
(2) Quantity of physics instruction and
(3) Contents of physics instruction

Ad (1): Of the three "types of learning experience" investigated (cf. Table 3), "Understanding and discovering the laws of physics" had a positive influence on most of the criterion variables. The study also permits the interpretation that instruction which simply informs students of physics' significance for society and everyday life without developing their competence to act is relatively ineffective (cf. also comments in section 3.2). Similarly, instruction geared to practical handling of equipment without the appropriate intellectual back-up cannot be expected to produce an impact evident in the long term (e.g. influence on the handling of appliances in later life). Thus forms of instruction should be sought which include and interrelate both aspects:

Scientific orientation and practical orientation, general cognition and specific reference to everyday life.

Ad (2): Although the study reveals a significant correlation between the number of weekly physics periods and the subsequent level of physics education among adults, and although there are no saturation effects, the influence here is not as great as that of the other factors and is restricted solely to the knowledge variables. A change in the quantity of physics instruction would have less of an effect than a qualitative improvement.

Ad (3): As far as the physics syllabus is concerned, it can be concluded from the study that the areas of physics dealt with during instruction are, at least in the long term, evidently not crucial. For this reason, the principle of exemplary teaching and learning - preferably geared to the interest of students - could be applied more often in the choice of subject matter to be taught.

Literature

/1/ Häußler, P., Frey, K., Hoffmann, L., Rost, J. and Spada, H.: Education in physics for today and tomorrow - results of a curricular Delphi-study IPN 116, 1988.

/2/ Häußler, P., Hoffmann, L. and Rost, J. in collaboration with R. Lauterbach: Zum Stand physikalischer Bildung Erwachsener - eine Erhebung unter Berücksichtigung des Zusammenhangs mit dem Bildungsgang. Kiel: IPN 105, 1986.

THE PHYSICAL-MATHEMATICAL CLASSES AND SUMMER SCHOOL ON PHYSICS AT MOSCOW INSTITUTE OF PHYSICS AND TECHNOLOGY

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The purpose and the main idea of this work is to attract the teenagers into the world of science, help them make a proper choice of life activities. Moscow Institute of Physics and Technology (Phys-Tech) is a unique institute unrivaled anywhere in the Soviet Union, it was founded in 1947 by the "fathers" of the Soviet physics P.L. Kapitsa, L.D. Landaw, I.V. Kurchatov & others.

It was intended for training talented & curious young people in a wide range of modern physics, for raising a new generation of scientists very enthusiastic & creative in scientific research. The main features of "Phys-Tech" system are:

- careful selection of most talented youth apt to creative activities;
- involvement of leading scientists in educating students, their close contact with the students;
- individual approach to each student, upbringing in the spirit of creative thinking & scientific curiosity;
- availability of up-to-date physics & technological experimental equipment used in the advanced scientific research institutes & design offices which are "base" institutions for Phys-Tech.

To keep up and raise its level Phys-Tech is in constant country wide search for the talented high-school students to make them interested and to attract to our institute. To this end Phys-Tech is involved in different activities, including the organization of so-called physical mathematical classes at Moscow Institute of Physics and Mathematics and "Summer School on Physics"

THE PHYSICAL-MATHEMATICAL CLASSES FOR TEENAGERS AT MOSCOW INSTITUTE OF PHYSICS AND TECHNOLOGY

It's no secret that our schooling system is typically inefficient & dull. The major goal is usually to " inject" an amount of knowledge rather then to teach students thinking & making conclusions. Our classes are primarily aimed at developing a personality, as well as creative power of each student. For this reason in our classes a lot of attention is paid to the selection of teaching stuff and careful enrollment of students.

The Institute professorial & teaching stuff is generally the Soviet scientists very active in scientific research work. The teachers in our classes are Institute professors of high qualification & experience in teaching general physics or higher mathematics.

To be enrolled into classes the teenagers are to write a paper & to have a talk with the examiner on physics & mathematics where they are supposed to demonstrate sharp mind rather than deep knowledge, the ability to quickly & non-trivially, solve problems.

The experience shows, that from a thousand pupils of high school, only 10 may really successfully learn in our classes. Every year we enroll 25 teenagers (age 14-15) and they study for 3 years: the 9th, the 10th, the 11th grades of high school. We have these classes in a typical high school not far from the Institute.

The basic teaching method in our school is understanding via problems emphasis on the problems of greater difficulty, a deeper presentation of material then in the text-books, confirmation of theory with experiments.

We do not resort to any special pictorial charts or tricks or to supporting plans, to special associative links. Since all these are ultimately aimed only at coaching.

It is the personality of the teacher, his deep knowledge of physics, his passion for the subject, approach to physics against the common background of natural sciences - that stimulate the student to learn. The teacher brings into the classroom the spirit & mentality of our Institute community, close contact with students & absence of barriers in teacher-pupil relations. The teacher the student solve problems as equal partners (jointly consider all tasks) and this in its turn stimulates independent & self education of the pupils.

Very significant & useful for developing creative power of advanced learners are the annual scientific conferences where the students are invited to make reports on their independent scientific research.

School children from all over the Soviet Union come to participate in these conferences, students from our classes participate as well. Creative power of such a student is very high as a rule. Beginning with the next year we plan to invite foreign students.

The other very important activity: Physical-Mathematical School by Correspondence which covers the work with the teenagers all over the Soviet Union.

There are 3 grades in this school as well, grades 9, 10, 11. Twelve tasks in physics and mathematics are mailed to each pupil every year. These tasks have more advanced treatment, then the text-books, and have test questions and problems. It should be noted that, all these tasks are composed by professors and teachers of our Institute. The pupil mails his work to the curator, a student who carefully checks his work, and mails back detailed analysis of the task solution. Every year the teenagers take the exams. They have a talk with the professor of our Institute or by correspondence. Long term experience showed this method is extremely efficient.

SUMMER SCHOOL ON PHYSICS

One of the various activities to make children interested & come to the Institute is so called "Summer School on Physics" where during two weeks selected high-school students are

attending lectures by Phys-Tech professors, make labs, solve some problems at the seminars, communicate with the senior students, thus " playing" real Phys-Tech student life.

Beginning with 1989, Moscow Institute of Physics & Technology is trying to expand these activities & to go out into the international level. In the summer of 89 the Institute conducted a two-week Soviet-American school of this kind. 25 American & 25 Soviet high-school students participated accompanied by several adults.

Naturally it is difficult to teach good physics students from different countries during two weeks. The goals we try to follow are:
1) help the students touch upon the problems they could study in the future;
2) to impart humanistic & social attitude to the problems considered.

Our program includes:
- seminars at which 5-6 students supervised by a curator solve problems of physics, discuss & make physical experiments;
- illustrative lectures on general physics;
- doing laboratory works with the Institute facilities;
- independent research in the Institute;
- lectures on modern problems of physics
- the course of seminars " Physics aspects in foreign policy", "Physics aspects in ecology"

There are a few words about the traditional program of summer school.

Last summer characteristics of sound propagation in gases at small pressures, general types of discharge were shown in the laboratory of vacuum engineering. Qualitative discussions of the observed phenomena were then supported by solution of problems. Very simple investigations were made of the dependence of gas discharge on pressure, applied voltage, shape of electrodes. Students studied fundamentals of sputtering of thin films. They jointly made a few samples which were presented to the American delegation.

In the laboratory of high temperature superconductivity an effect was demonstrated named the Meisner effect, the explanation of this physical phenomenon was also given.

In the optics laboratory the students were told about the history of development of the nature of light & basic statements of modern theory. They got to know the laws of light propagation when it passes through the interface between two media with different refraction indices, the phenomenon of complete internal reflection & binary refraction of beams, interference in thin films. Group of students could make independent research where they experimentally observed & tried to explain various optical phenomena of liquid crystals.

I'd also like to consider another scope of problems which we are going to include in our future summer schools. Today when the international relations are becoming much warmer, lots of external & internal policy problems are being reconsidered, including the problem of strategic stability. We are approach quite a new system of collective security. All this makes it extremely useful & interesting to have a course of lectures &

discussions or seminars which could be referred to as " Physics aspects in foreign policy"

This course contains illustrative examples in physics estimating technological ability of humanity to produce space based weapons. Much attention in this hours could be paid to anti-ballistic missile systems. Although many politicians think the idea of producing super-expensive space security system mostly belongs to the past, potential threat from the space is a reality, however.

Unfortunately, the evolution of human thought & discoveries of new physical phenomena in some cases turn out to have a negative effect on human progress. Thus besides purely educational goals, the present course is aimed at making the students understand the problems facing our countries. The discussions & seminars presuppose the students know the course of high school physics & they are interested in the problems of foreign policy.

One of the main goals of our school is to get the students know the physics aspects of the most significant problems of the world, one of the them is environment protection. Approximate numerical estimates are developed in order to quantify a variety of environmental effects that result from energy production. The results of the calculations are consistent with either direct observations or with more complex calculations. Our course covers some of the possible environmental effects:

1) the greenhouse effect caused by increased carbon dioxide in the atmosphere;
2) loss of coolant accidents in nuclear reactors;
3) increased radon concentrations in buildings with very low air infiltration rates;
4) acid rain from the combustion of fossil fuels;
5) ozone in stratosphere and so on.

Conclusion

So we expect to continue these activities and propose to conduct next International Summer School on Physics. I'd like to point out that the Institute curriculum covers in accordance with the scopes of Phys-Tech departments all problems of physics, chemistry, astronomy, electronics, computer science, biophysics, biochemistry, space-research, ecology, natural-science philosophy and arms control. And the future summer physics schools can focus on all these sciences.

We believe it would be possible to organize a non-currency exchange of 15-20 students & some 5 adults on every part. Every organization questions may be solved in cooperation.

EVALUATION AND QUALIFICATION OF PHYSICS EDUCATION: REFORM IN DANISH SECONDARY SCHOOLS

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Introduction

When discussing evaluation and qualification in physics education, it is essential to destinguish between two different levels:

(1) evaluation and qualification of students within an existing structure and existing contents of physics education
(2) evaluation and qualification of the structure and contents of physics education itself.

In this paper we shall confine our discussion to the higher level, i.e. level 2.

Ideally, any kind of education ought to have built-in feed-back mechanisms for evaluation and ensuing qualification, but in most cases only students are evaluated at their final examination - and the results of these examinations are rarely brought to bear on the education itself.

The feed-back mechanisms may be pictured as a spiral staircase, hopefully leading to higher levels:

Step 1: Elucidating the underlying philosophy and the aims and goals of the education in question, if these have not been formulated explicitly.
Step 2: Reviewing the existing structure and contents of the education: Number of lessons (and their length) and topics to be covered in the various grades, balance between experimental and theoretical activities etc.
Step 3: Evaluating students' knowledge and abilities (usually also

tested at examinations) and attitudes (seldom tested) as well as teachers' experiences and attitudes.

Step 4: Assessing the results of the evaluation: What is good and what is bad?

Step 5: Making recommmendations on a general level, referring to the findings in Steps 1 and 2, e.g. suggesting a change of philosophy, omission of some topics, inclusion of other topics, etc.

Step 6: Making detailed recommendations on single topics and types of experimental activities, perhaps even writing a syllabus with suggestions for actual teaching.

Step 7: Implementing the reform by organizing in-service teacher training and stimulating potential authors of textbooks etc.

Step 8: Allow things to settle. Return to Step 3 (since the results of Steps 1 and 2 ought to be quite clear by now!)

The way we were

Compulsory education in Denmark lasts for 9 years ("Folkschool"), beginning at age 7. In grades 7 - 9 physics/chemistry is mandatory with 2 weekly periods, each of 45 min. After grade 9 about 25% of the students continue their general education in upper secondary schools ("Gymnasium") and another 10% enter the gymnasium after an optional 10th grade in Folkschool. Before starting the gymnasium, the student must choose between a linguistic line and a mathematics line. So it was, and so it still is.

At the time of the beginning of the evaluation to be described (i.e. 1982) there was no physics in the linguistic line. In the mathematical line, every student had 3 weekly periods of physics during the first grade and after this a choice between high level and low level mathematics and physics. Low level physics was 2 weekly periods for the last two grades, high level physics 3 weekly periods in the second grade and 5 weekly periods in the third. One third of the new students chose the linguistic line (80% of them girls), while the remaining two thirds chose the mathematical line (44% of them girls). About one third of the mathematical line students chose high level physics and mathematics. So much for structure and statistics!

The latest reform in the folkschool happened in 1976 and in the gymnasium in 1961. The philosophy behind physics education is best described as science centered: In the folkschool, kinetic energy, potential energy and energy conservation were to be the basic concepts, whereas gymnasium physics was defined through a compendium of 169 formulas. At all levels, experimental work should have a central role, but usually experiments were of the cookery book type with zero degrees of freedom.

Evaluation

In 1981 we left our former fields of physics research and began research in physics education. The following year, we started (in collaboration with physics teachers) a longitudinal investigation of interests and attitudes among gymnasium students ("Gymnasium-Physics-Project", 1982-85), supplemented by a questionnaire to gymnasium physics teachers (1984). The results are described in detail in a number of project reports (in Danish) and the main findings have also been published in English (Nielsen and Thomsen, 1985, 1986 and 1988). Very briefly, the essence of our work is that a majority of students perceive of physics as difficult, abstract, and unrelated to real life. This did not hold for students having chosen high level physics, but many students on low level physics and in the linguistic line admitted having based their choice on a desire to avoid physics. The teachers admitted that there were large problems in the common first grade and in the low level physics line and gave a number of suggestions for improvements.

The above-mentioned investigation was supplemented by a test with "alternative framework" and "Piagetian" problems in 1982. The test was done from grade 8 in the folkschool to the end of the gymnasium and the results were in accordance with international findings on similar tests.

Summing up the findings of the evaluation phase (Nielsen and Thomsen, 1988), we concluded that physics education in Denmark is haunted by the same problems as elsewhere:

- Intellectual capacity of students compared to the demands of the curriculum
- Persistency of alternative frameworks
- Negative attitudes and interests among students

As a fourth problem, "girls and physics" was added, since on the average girls consistently did worse on tests and had more negative attitudes towards physics.

In 1986-87 the above-mentioned investigations were supplemented by a test of students' understanding of energy in grades 8 and 9 in the folkschool (in collaboration with Albert Chr. Paulsen, Roskilde University, and Helene Sørensen, Royal Danish School of Educational Studies). The test partly consisted of everyday problems on energy conservation and transformation, partly of problems more like the standard problems treated in the folkschool (e.g. energy transformation in the mathematical pendulum). Teachers of the tested classes were asked to guess their students' average performance and for most problems overrated to a large extent. On the whole, the students did rather poorly, and the conclusion was that the concept of energy was not properly internalized in the minds of the students.

Finally, the fifth problem usually mentioned is teachers' poor background in physics. We did no investigations of this since it was quite clear that this problem was a real one for many folkschool teachers, but not for gymnasium teachers. This fact is connected to the teacher education system in Denmark: Folkschool teachers are trained at teacher training colleges emphasising general pedagogy and psychology, gymnasium teachers are trained at universities and must have at least a B.Sc. in physics and a M.Sc. in physics, mathematics or chemistry. Besides, recent investigations have shown that the percentage of physics/chemistry teachers in the folk school, who have taken a special course in physics or chemistry at one of the teacher training colleges, may be as low as 50%.

The results of our evaluation attracted a lot of attention - both from teachers and the responsible authorities, including the Ministry of Education.

Recommandations

In a final report on the Gymnasium-Physics-Project we summarized the results, presented our view on the problem causes, and gave a number of recommendations. The English version of this report is (Nielsen and Thomsen, 1988). Our main recommandations were the following:

- The traditional science centered approach should be changed to a human centered approach.
- Not only the product of physics ("169 formulas") should be taugt, but also the process.
- Physics should not be taught solely for its own sake, but as a truly interdisciplinary subject.
- The 'hard core' of physics concepts should be supplemented by a number of 'dimensions' as e.g. the worldview of physics, physics-technology-society relationships and history and philosophy of physics.

These suggestions for a basic educational philosophy were supplemented by a number of recommendations on other measures, as e.g.:

- Science teaching should start at an earlier age, e.g. in grade 3 or 4 in the primary school.
- An integrated physics/chemistry course should be mandatory in the linguistic line of the gymnasium.
- The systematic teaching of physics should be supplemented by thematic approaches.
- The number of "hard-physics" concepts should be decreased and carefully selected. More time should be allocated to each concept, emphasising quality of learning instead of quantity of teaching.
- The balance between experiment and theory should be given careful consideration.
- Teachers should be stimulated to change over from an (implicit) positivist to a constructivist philosophy of learning.
- Massive in-service teacher training should be organized as an integral part of any major reform.

It was not expected that these recommendations could remedy all the problems, but experiences from e.g. the Dutch PLON-project (Dekker and van der Valk, 1986) indicate that improved attitudes and interests will result. In 1985-86 when our recommandations were published there were few projects - and no conclusions - on how to change teaching in order to improve on either the intellectual capacity problem or the alternative frameworks problem. Thus we did not have much to say on these matters at that time.

Reforms

In 1985 the Danish parliament started work on a gymnasium reform allowing more options for the students. Interesting from a physics point of view were

(1) A mandatory, integrated course of mathematics-physics-chemistry was introduced in the linguistic line in grades 1 (3 weekly periods) and 2 (4 weekly periods).
(2) In the mathematics line, physics should be mandatory in grades 1 and 2 (3 weekly periods), optional on a high level in grade 3 (5 weekly periods).

At the same time, two committees were appointed to go deeply into the physics syllabus in the folkschool and the gymnasium, respectively. One of us (HN) was a member of the gymnasium committee, which also comprised representatives from teachers, universities and industry. Correspondingly, the committee for the folkschool had representatives from teachers, teacher educators, and 'parents'. Both committees ended up with detailed suggestions for new curricula in close agreement to our recommendations, the gymnasium committee in 1987, the folkschool committee in 1989. The gymnasium reform was put into practice in 1988, and teaching according to the new folkschool reform will commence in August 1990.

Gymnasium

Physics education is now based on a physics 'core' and 5 'dimensions'. In grades 1 and 2 (the mandatory part) the core is (in broad terms):

- Energy
- Electrical circuits
- Waves
- Atomic and nuclear physics
- Linear Mechanics

In grade 3 (optional):

- Mechanics
- Electricity and magnetism
- Nuclear and particle physics

This is a rather conventional physics core, but it must now be seen and taught through the following dimensions:

- Physics and the world around us
- The physicist's world-view
- Examples of modern technology
- The physics-technology-society relationships
- History and philosophy of physics

Part of the teaching must be thematical, i.e. be organized around a particular theme within one of the above mentioned dimensions, other parts should take place in a more conventional systematical setting, e.g. rounding up a thematical unit.

The extent of experimental work is unchanged (about 30 periods in mandatory physics and 30 additional periods in optional physics), but now there must be a progression from rather simple experiments in the beginning of the gymnasium to more demanding experimental projects of about 10 periods in the physics laboratory. The large experimental projects are supposed to be organized in various phases, including initial periods of problem idenfication and experiment planning, and final periods of report writing and evaluation. The progression is thus from the usual zero degrees of freedom to three degrees of freedom: (1) Choosing problem for investigation, (2) Planning investigation, (3) Performing investigation and obtaining results. (Andersson, 1989).

Folkschool

Also the Danish folkschool is now leaving the science centered philosophy. In the future, physics education is to be built on 5 'central areas of knowledge and skills':

- Methods and thinking in Physics/Chemistry
- Matter and phenomena around us
- The scientific world-view
- Life and environment
- Technology

It is explicitly stated that the 'process' side must have at least the same weight as the 'product' side, that pupils' independent experimental work must be strengthened, and that theory introduced must have an application value, e.g. in known phenomena and practical problems.

Implementation

At the time being, the folkschool reform is still to come, and we therefore confine ourselves to discussing the implementation of the gymnasium reform.

Although the reform had been preceded by a wide-spread debate among the physics teachers in the gymnasium and although some teachers certainly to some degree had included one or the other of the five dimensions in their teaching, it is probably fair to say that as a whole the group of physics teachers were not well prepared for the reform. As a consequence, the Ministry of Education allotted extraordinary funds for an increased amount of in-service teacher training activities and appointed a committee to be responsible for the organization of the teacher training program. This committee soon decided that due to the very limited amount of money available (approximately 2000 DKK per physics teacher) the most sensible way ahead would be to concentrate the effort on creating the basis for a number of regional in-service teacher training courses. These courses were to be developed and implemented by working-groups ("think-tanks"), the members of which were carefully chosen among active and interested teachers from universities and upper secondary schools.

Think-tanks were appointed for the innovatory areas of the new physics education, i.e.:

- World-view of Physics
- Physics-Technology-Society

- History and Philosophy of Physics
- Experimental Projects
- Thematic Teaching

Members were partly physics teachers with prior experience in the area concerned, partly university staff members.

In the following, we shall report on the work carried out by the think-tank commissioned for the historical-philosophical dimension since we were heavily involved, and the work of this think-tank turned out to be paradigmatic for the other think-tanks. Besides ourselves, the group consisted of two physics teachers, one history teacher and one teacher of Danish from upper secondary schools in our local area, and one historian of physics from the University of Aarhus. Each member of the group had prior experience in the field, and most of us had in fact already published books on history of physics for gymnasium students.

In our discussions within the group we rapidly realized that our task was formidable: Firstly, we had to convince the average physics teacher (who previously had not been actively involved with the history and philosophy of physics) that history of physics is interesting and that the students really may benefit from it. Secondly, we had to teach him/her some interesting examples from the history of physics along with suggestions for actual use in the class-room. And, thirdly, we had to convince the teacher that he/she would also be able to teach the students on the historical-philosophical dimension without any problems.

The final result of our work was (1) a teachers' guide, and (2) an inexpensive training programme which will enable every single physics teacher to acquire a minimal introduction to the subject. As an almost integrated part one should also consider (3) the books for students on different aspects of the history of physics, which the individual members of the working group had already written in advance - or which they began writing. We shall not go into the details here since an account is given in a forthcoming paper (Nielsen and Thomsen, 1990)

The teacher training program was designed as two stages. The first stage was a three-day seminar, held in August 1988, for a selected group of some 30 physics teachers. The participants were known to us as having previously shown an active interest in history and philosophy of physics and came from schools all over the country. At this seminar the above-mentioned book was presented and subjected to a thorough discussion. The participants were then given the responsibility for arranging (in close collaboration with local branches of the Danish Association of Physics Teachers) a nation-wide series of regional meetings. At these meetings one of the members of the think-tank introduced the dimension and the teachers' guide (which in the meantime had been sent to every physics teacher in Denmark), and concrete proposals for teaching were discussed. This second stage became operational during the Fall of 1988 and continued during 1989 and 1990, by which time almost every physics teacher in the country had had the opportunity to attend to at least one of these one-day courses.

With very few exceptions, the reactions of teachers participating in the meetings have been positive as regards the historical-philosophical dimension in general and the usefulness of the teachers' guide in planning and running teaching sequences for students in particular. The real test, however, will of course be the reactions of the students when they are confronted with teaching material of this kind.

It should be mentioned that the reform has inspired not only members of the think-tanks to produce teaching materials, but also quite many physics teachers: A few series of books covering the core and giving suggestions for thematic and dimensional teaching have appeared, and presently about one book or booklet is appearing every month on such diverse themes as e.g 'The electric kitchen', 'Seeing and hearing', 'The Manhattan Project', 'Buoyancy' and 'Ice-Physics'.

A corresponding development is expected to take place in the folkschool during the next few years.

The future

As mentioned earlier in this paper, we do not believe to have solved all the problems in physics education through the gymnasium reform in Denmark. We do believe, however, that the reform will at least change the attitudes of many students to physics in a positive direction. We also know that this is just the beginning of a process that may take quite a few years to unfold, since it relies on a corresponding change in the teachers' conceptions of how physics education ought to be in the upper secondary school.

To promote this change, we have started a working group together with some gymnasium physics teachers, with the aim of developing suggestions and materials for teaching within a conctructivist framework. Pilot trials will take place in the Fall of 1990. Another working group is preparing a book presenting the constructivist philosophy and suggestions for using it in classroom practice.

Too often, reforms are carried through without any kind of feedback. We do not want this to happen again and have consequently suggested a large scale evaluation programme to the educational authorities. If the appropriate grants are given, renewed evaluation will take place in the gymnasium in 1992-94 and in the folkschool in 1994-96.

References

B.Andersson: Science in compulsory school - Research results and new ideas. Utbildningsförlaget, Stockholm, 1989 (in Swedish).

J.A.Dekker and A.E.van der Valk: Pre-university physics presented in a thematic and systematic way: experience with a Dutch Physics Curriculum Development Project. European Journal of Science Education, Vol. 8, No.2, pp. 145-153 (1986).

H.Nielsen & P.V.Thomsen: Physics in Upper Secondary Schools in Denmark, I - III.
European Journal of Science Education, Vol. 7, No. 1, pp. 95-106 (1985); Vol. 8, No. 3, pp. 315-324 (1986). International Journal of Science Education, Vol. 10, No. 2, pp. 189-202 (1988).

H.Nielsen & P.V.Thomsen: The History and Philosophy of Science in Physics Education.
International Journal of Physics Education, Vol. 12 (1990). In press.

AIMS AND GOALS OF PHYSICS TEACHING ON PERSONAL LEVEL

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Abstract

Aims and goals are the criteria behind evaluation and qualification of physics education in any processoriented analysis. They have been considered traditionally from the viewpoint of educational systems and of the subject putting emphasis on the selection of the contents of physics courses. However, there is also a demand for a more personal approach: the Finnish schools have as the principal general goal "the development of the personality of each pupil". This effects even teacher education, and we find it necessary to analyze in this perspective even the education of physicists for industry as well as research teams.

We have selected four groups of personal aims and goals of the personal development of physicists and physics teachers to structure our analysis as follows:

- Cognitive skills (reasoning ...)
- Psychomotor skills (related to laboratory skills)
- Human relations skills (related to team work etc.)
- Skills of an autonomous personality (initiative, responsibility, decision making skills, ...)

This approach is shortly discussed in connection of our research and development work for activating a wide spectrum of pedagogical approaches including the use of modern educational techniques in the schools and in teacher education.

1. Introduction

Teaching and learning processes can be analyzed from the cybernetic viewpoint utilizing obvious analogies with theories of industrial processes and with automata in general. Evaluation considers not only giving marks to pupils or students. It also provides teachers with the feedback, which is needed for regulating the pedagogical processes so that they lead to best possible results. A simplified model for educational processes can be seen in Figure 1. The feedback signal is here essentially the difference between the learning outcomes and the aims and goals.

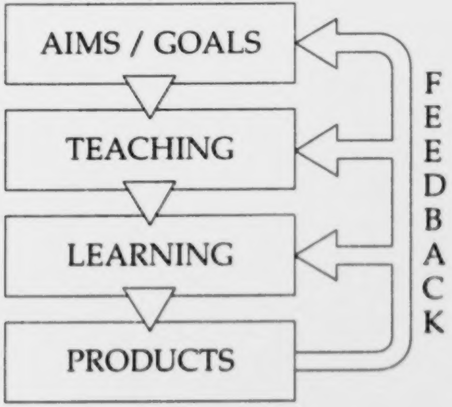

Figure 1. A simplified model for educational processes

As we can see in the above analysis, aims and goals are the criteria behind evaluation and qualification of education. It is obvious that this holds good also in the field of physics education. The goals have been considered traditionally from the viewpoint of educational systems or of the subject area putting emphasis on selection and arrange ment of the contents of physics courses. However, there is also a demand for a more personal approach: the Finnish schools have as the principal general goal "the development of the individual personality of each pupil". This general goal was introduced in the Finnish comprehensive school in the sixties. There was for a long time a major discrepancy between this general goal and the subject oriented ones, which were emphasizing learning of specific subject areas only. However, by the last revision of the national curriculum in 1985 the aspect of personal development of pupils were introduced also in all subject oriented goals. This had obvious effects even in evaluation of physics teaching and learning. We see that there should be a thorough analysis of the key aspects of evaluation on all levels of physics education including the evaluation of the education of physics teachers.

2. Personal development and goals of physics teaching

2.1 The outline of aims and goals of physics teaching

We have selected four groups of personal aims and goals of the personal development of physicists and physics teachers. The following skills have to be developed by each individual:

- Cognitive skills (reasoning ...)
- Psychomotor skills (related to laboratory skills)
- Human relations skills (related to team work etc.)
- Skills of an autonomous personality (initiative, responsibility, decision making skills, ...)

This approach is discussed below in connection of our research and development work for activating a wide spectrum of pedagogical approaches including the use of modern educational techniques in schools and in teacher education.

2.2 Cognitive skills

The relevant cognitive skills can be listed in different ways and here we can benefit from the well known classification of Gagne, which we modify for the present purposes. We list these skills as follows:

- recognizing, remembering relevant knowledge;
- organizing and classifying knowledge, formation of general views;
- application of knowledge;
- updating information, estimation of its reliability, accu racy and applicability;
- inductive reasoning;

- deductive reasoning;
- use of analogies and symmetry arguments;
- creative problem solving.

Its is important that students are trained in working on all these cognitive levels. It is also necessary that evalua tion procedures test performance on both basic levels like memorization or classifying information, and on intermediate and higher levels like application and creative problem solving.

2.3 Laboratory skills

In physics laboratories a different set of skills has an important role. These skills have been previously analyzed by numerous authors (cf. Erätuuli & Meisalo 1982, 1985; Meisalo & al. 1990), and they have relevance also for vocational training. These skills include

- ability of accurate and comprehensive observation;
- dexterity;
- hand - eye coordination;
- control of complex processes like assembling experimental setups, constructing measuring instruments, or performing measurements;
- evaluation of obtained data;
- planning of experiments.

These skills can be tested partly by paper and pencil tests, but it is essential that some possibilities for observation of student laboratory work, or practical test items are included in the evaluation procedure.

2.4 Human relations skills

It is more and more typical that physicists as well as other scientist and engineers work in teams. Thus it is also important that physicists have skills that are needed in complex cooperative situations. Physicists also need skills of supervisor. instructorand communicator. Thus important skills include

- skills of communication, oral and written reporting, foreign languages;

- cooperative skills, readiness to effective division of labor, empathy;
- flexibility, adaptability to new social circumstances;
- skills of negotiation, ability to reach mutual agreement;
- skills of dissertation and argumentation;
- leadership.

These skills should be trained also in connection of physics teaching, but usually it is not considered proper to include these in physics evaluation. However, for instance foreign language skills form a part of general studies in Finnish university education and training in negotiation skills is becoming more and more important in education of engineers etc. In teacher education the importance of this goal area is obvious and is evaluated as a part of pedagogical studies.

2.5 Skills of an autonomous personality

Physics teaching has always emphasized individual work of pupils. However, it has been seldom analyzed, what autonomy and freedom to independent work actually mean in practice (cf. Meisalo & al. 1990). In this work we wish to identify some of the skills of an autonomous personality, which are cultivated by activities allowing intellectual freedom to students. These include

- initiative
- self respect
- willingness to work properly
- thirst for knowledge and truth
- hunger for results
- ability to make decisions
- readiness to take responsibility
- readiness for continuing education

This goal area is difficult to evaluate, but it has important effects in the success in studies as well as in work in general. Autonomous studies and project work seem to be best suited for both training and evaluating the skills of an autonomouspersonality.

2.6 Pedagogical approaches and their analysis

It is often regarded necessary to concentrate in physics teaching in presenting the subject matter as effectively and concretely as possible, and to avoid concerns on any other goal areas. Demonstrations and student laboratory work are used as far as possible to add to the lecturing and solving routine mathematical problems, which take the major part of physics courses. Individual work is appreciated and any help from other students is considered to be tantamount to cheating. However, recent research shows that cooperative learning bearing on students work in complex social situations, can be even more effective in developing higher order thinking skills than traditional approaches.

In the above presentation of goal areas we included already some general comments on pedagogical approaches and evaluation procedures. However, it is necessary to have possibilities for more thorough analysis. We have developed for this purpose the Multidimensional Classification of Pedagogical Approaches or MCPA-analysis, which is able to bring up the essential features of different teaching methods (Meisalo & al. 1990). We have used this method both in design of evaluation studies and in development of pedagogical guides for teachers.

In research and development projects on physics education we are to remember also the growing role of information technology both in the physics (experimental and theoretical) and in education. Computers have in education far wider role than can be expressed by the term computer assisted instruc tion. We have used the concept "Market Square" or "Extended Market Square Model" (Figure 2) to illustrate the possibili ties for open approaches and creative problem solving (Meisalo 1989). Here students should be free to use different instruments and tools for their problem solving while the teacher is acting as a consultant and supervisor. In this picture we may add the use of computers to help in the evaluation process.

3. Testing methods in different goal areas

It is essential, that different goal areas are included in testing procedures and even so that most important goals and aims are emphasized in the evaluation process.

For the cognitive area it is important that students are trained in working on all cognitive levels. It means that evaluation

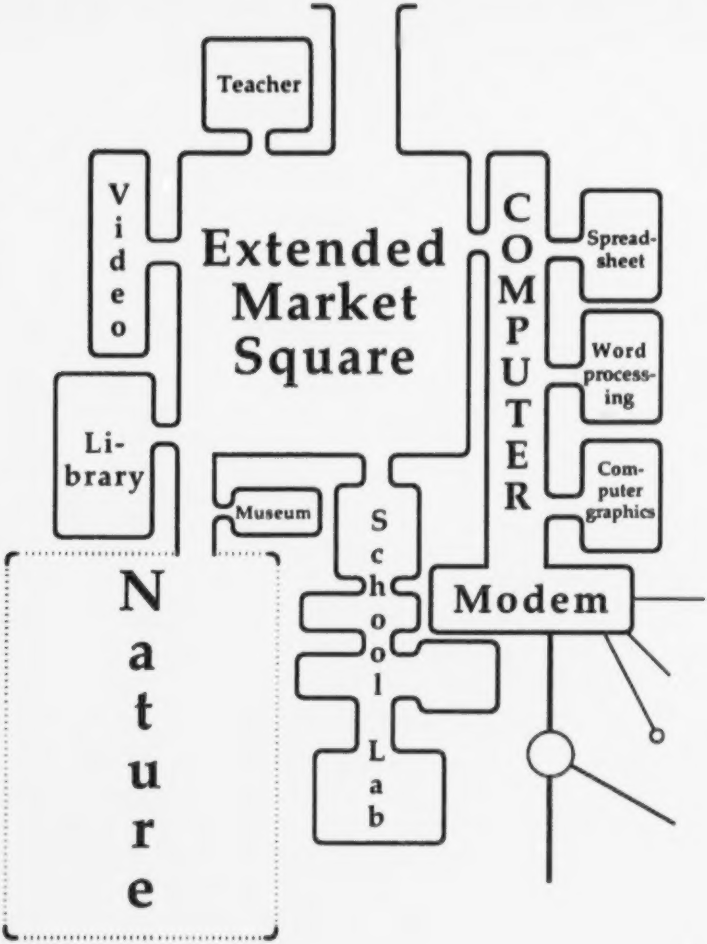
Teacher
Video
Extended Market Square
COMPUTER
Spread-sheet
Word processing
Computer graphics
Library
Museum
School
Lab
Modem
Nature

Figure 2. Extended Market Square Model

procedures have to test both basic skills like memorization or classifying information, and intermediate as well as higher cognitive skills like inductive and deductive reasoning, application and creative problem solving. Teachers are usually reasonably well trained for this kind of testing, but problem solving is not usually approached in a very creative way.

Physics is an experimental science and thus it is most essential, that related skills are properly emphasized. Even the practical skills can be tested partly by paper and pencil tests, or evaluation of written laboratory reports. More direct methods include for instance observation of student laboratory work as a form of continuous evaluation. Practical test items can also be included in tests. These possibilities should be used more frequently on all levels of education.

Human relations skills are also important as well to physicists as to teachers, but as commented above, it is not considered proper to include these in physics evaluation. However, for instance the importance of foreign language skills to professionals in all fields has been very much emphasized recently. The testing methods are moving from reading comprehension tests towards testing the ability to take part in scientific discussions, negotiations, etc. We see also that training in negotiation skills is becoming more and more important in education of professionals including for instance engineers. In teacher education the importance of this goal area is obvious and social skills in a classroom setting are evaluated during pedagogical studies. So far the evaluation in this area has been separated from physics evaluation, but as we see, there are obvious connections.

Skills of an autonomous personality are difficult to evaluate, but they have important effects in the success of all students. This applies both to their studies as well as to their professional career in general. Autonomous studies and project work seem to be the best suited methods for both training and evaluating the skills of an autonomous personality. It may be also useful to analyze the current pedagogical approaches for limitations to the autonomy of the student. In this area it may not be important to give any marks, but it is certainly useful to give positive feedback to the students.

4. Discussion

Quality and effectiveness in physics teaching means reaching different goal areas in a balanced way. Thus all these areas have to be included in the evaluation process. It is argued that experimental methods and laboratory work are not properly emphasized in evaluation. Hardly any importance is put in the other goal areas, social skills and skills of an autonomous personality. However, these may be crucial in the education of successfulprofessionals of tomorrow. It is also necessary to use a wide spectrum of different pedagogical approaches and to activate them in different situations according to the feedback.

The above view in physics teaching may be alien to many presentday teachers. It is meant to have a futurological perspective and to help in planning pedagogical experiments for more flexible, longlasting and more widely applicable skills for physics education.

References

Erätuuli, M. & V. Meisalo 1982. Fysiikan ja kemian oppilastöiden evaluaatio. Lähtökohtia peruskoulun yläasteen fysiikan ja kemian oppilastöiden evaluaatiomenetelmien kehittämiseksi. (Evaluation of laboratory work of secondary school pupils. A preliminary study to develop methods of evaluation of practical work in physics and chemistry. (In Finnish) Department of Teacher Education, University of Helsinki, Research Report no. 7

Erätuuli, M. & V. Meisalo. Fysiikan ja kemian oppilastöiden evaluaatio II. Luonnontutkimustehtävät fysiikan ja kemian kokeissa. Evaluation of laboratory work of secondary school pupils II. Science research tasks in student evaluation. (In Finnish) Department of Teacher Education, University of Helsinki, Research Report no. 35

Meisalo, V. 1989. The Finiste Network and pedagogical research. In Innovations in the Science and Technology Education. Information Bulletin of the National Board of General Education, Finland 2/1989, 43- 51

Meisalo, V., M. Erätuuli & E. Capaccio 1990. Evaluation of laboratory work in Secondary School Science Teaching. Development of evaluation methods for the Finnish comprehensive school with emphasis on the biological sciences and chemistry. University of Helsinki Department of Teacher Education, Research Report no. 84

PHYSICS TEACHER EVALUATION BY STUDENTS: A REPORT ON 10 YEARS OF EXPERIENCE AT THE UNIVERSITY OF INNSBRUCK

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Abstract About 10 years ago, the board of so–called 'physics students representatives' at the University of Innsbruck, Austria, started to evaluate the teaching performance of each member of the physics faculty. This has been done routinely ever since at the end of a term through a multiple–choice questionnaire, to be filled in anonymously by each student in the audience of a course. The statistics of the various courses are collected on a single sheet, which the chairman of the 'physics students representatives' hands over to the physics teacher concerned. In the past, they were posted on various university bulletin boards, and several times they were published in the Student Monthly Magazine. The paper briefly addresses a number of issues of interest in the context of such a physics teacher evaluation by students, such as the evolution of the contents of the questionnaire from the initial to the present form, and the evolution of the manner of extracting an evaluation from all the answers given by the students. It also discusses the ways by which the students attempted to bring these evaluations to bear on the future teaching performance of those teachers who had done poorly in the evaluation, and to what extent these measures have been effective.

1. Introduction

The following report on the Innsbruck experiment on 'physics teacher evaluation by students' is organized into a number of questions and corresponding answers, on the one hand, because this helps to keep it compact, and on the other hand, to allow an interested reader to go immediately to the points of interest to her/him.

2. When and why was 'physics teacher evaluation by students' introduced?

Following the example of the physics department of the University of Karlsruhe, German Federal Republic, 'physics teacher evaluation by students' was introduced by the author in 1978 in a period of discussion among the faculty of the physics department of the University of Innsbruck concerning possible options to improve the quality of certain courses that did not seem to be well received by the students. After that, this task was taken over by the so–called 'physics students representatives', who are elected every two years by the general assembly of all physics students, and who act on behalf of the students in much the same way as the executives of some trade union.

3. What was hoped that 'physics teacher evaluation by students' would achieve?

It was intended to provide the lecturers with some feedback as to how their teaching efforts were received by their 'consumers', the students. One the on hand, it was hoped that those lecturers whose courses were criticized would make an effort to do better in the evaluation next time round, and, on the other hand, that in assigning a lecturer to a certain course, the head of department would give preference to those teachers that did well in the test.

4. What kind of courses are evaluated by students?

- All courses that are compulsory according to the curriculum
- Any course given by a new faculty member
- Any course with an audience of more than 10 students
- Any course if the teacher asks for an evaluation
- Any course if a number of students that attend it ask their 'physics students representatives' for an evaluation

5. How is the 'physics teacher evaluation by students' carried out?

It is carried out by means of an anonymous questionnaire, the current format of which is given in the Appendix, asking the student to give graded answers by marking with a cross one of five boxes. There are questions on 'General Impression', 'Course Contents', 'Presentation', and 'Exercises', where the gradation of the answers is intended to allow an objective comparison between different courses. There are also 2 questions about the student herself/himself, in order to provide the teacher with information on

- has the course been attended according to the curriculum?
- has the audience been experimentally or theoretically inclined?
- has the course also been attended by future secondary school physics teachers?
- has the course also been attended by mathematics students?

6. What has been the time evolution of the questionnaire format?

The original version asked 37 questions, 6 of which required lengthy verbal answers. Small wonder that it was soon found to be too long. The current questionnaire asks only 14 to be answered by marking boxes, which in 8 cases can optionally be supplemented by verbal comments. The original version also asked questions concerning the educational background of the student, because it was recognized that the answers to certain questions in the questionnaire were strongly correlated with this quantity. However, on evaluating a particular course, the 'physics students representatives' found it impossible to bring out the many cross-correlations in any meaningful way.

7. What is the student participation in the physics teacher evaluation?

In order to evaluate a particular course (which is always done near the end of it), the 'physics students representatives' ask the lecturer for 20 minutes at the beginning of a lecture in order to carry out their evaluation. In the absence of the lecturer, the distribute the questionnaire and tell the students to answer them right then and there. It has been found that in this way the turnout is much higher than if the students are asked to answer the questionnaire at home and return it some time later. Evaluating a course near the end of it, however, can have a severely distorting effect on the result: suppose that a course is taught so poorly that by the time of its evaluation. a large number of frustrated students have already given up attending it. Then these students do not take part in the evaluation. although they would have given the course its poorest marks.

8. How are the returned questionnaires condensed into a teacher evaluation?

The original version of the questionnaire contained one all–important question. namely. "Is your overall impression that this course is excellent. fair. average. poor. or very poor?". and the average mark of all answers to this question alone was taken to be the criterion for evaluation the course. Then these results were collected for all the courses evaluated given in a particular semester. and. by comparing them. a table with the standings of the physics teachers was made public. by posting it on various university bulletin boards and by publishing it several times in the Student Monthly Magazine. The answers to all the other questions were only used to give the lecturer additional information on how certain aspects of her/his course were assessed by the students. This philosophy has meanwhile been abandoned. because it was felt that the publication of the results was too drastic a method. Now. the evaluation is derived from a consideration of the answers to all questions. and the 'physics students representatives' hand the results to the teacher concerned in the course of a private discussion.

9. How have the teachers reacted to their evaluation?

At first. there was just a general surprise that now not only teachers were evaluating the performance of their students. but also students were evaluating the performance of their teachers! Also. there was a general curiosity of how one would do in this evaluation. and everybody expected to find herself/himself near the top end of the table of standings. When it turned out that some teachers always did well. and others always did badly. only those who did well seemed to maintain a lively interest in their regular evaluation. On the other hand. most of the teachers. who came out regularly at the bottom end of the table. tried to play these results down by claiming the students to be not sufficiently qualified to evaluate a 'professor'. And a few of them even reacted downright aggressively. when finding their poor evaluation made public by the 'physics students representatives'.

10. What steps have students taken to improve poorly evaluated courses?

First. the students tried to put poor teachers under pressure by the passive means of bringing their poor performance to public notice. However. faced with the aggressive reaction of some influential faculty members (cf. Sect. 9 above). this strategy was abandoned and replaced by the more active means of seeking a conservation in private with each member of the group of underachieving teachers. This approach has proved somewhat effective in certain cases. but not in others. Very recently. therefore. the 'physics students representatives' have taken to exploiting a certain regulation of the Austrian University Law. This regulation calls upon a certain committee. made up in equal parts of full and associate professors of physics. of assistant professors of physics. and of 'physics students representatives'. to delegate some of its members to attend criticized courses. And. if they are found to be deficient. to make suggestions as to how they can be improved. When the 'physics students representatives' came forward with this suggestion during the latest meeting of this committee. those professors whose teaching is regularly criticized by the students, voiced a passionate protest. But since the current group of 'physics students representatives' is very pursuing, this is certainly not the last word on the matter. But already at this stage there is one desirable effect: the issue of excellent teaching has been put very noticeably into focus again among the faculty of the physics department of the University of Innsbruck.

Appendix: The Current format of the multiple–choice questionnaire

COURSE EVALUATION

Course name: ____

Personal Data:

1) Which semester are you: ________________________________

2) Your study goal:	Physics	Research:	experimental	☐
			theoretical	☐
		Secondary School Teaching		☐
		Undecided		☐
	Mathematics			☐
	Other: ________________________________			

General Impression:

(1) Would you recommend this course to other students?
yes, highly ☐ ☐ ☐ ☐ ☐ no, not at all

(2) Did this course deepen your physical understanding?
yes, very much ☐ ☐ ☐ ☐ ☐ no, not at all

(3) Do you feel that you have been taught meaningful and useful material?
yes, very much ☐ ☐ ☐ ☐ ☐ no, not at all

Course Contents:

(4) Did the lecturer make a interesting selection of contents?
yes, very much ☐ ☐ ☐ ☐ ☐ no, not at all
Which parts were interesting, which not? Comment:

(5) How do you assess the amount of material treated?
much too much ☐ ☐ ☐ ☐ ☐ much too little
If too much, where would you reduce, if too little, what was missing?

(6) Was material treated that was already well–known to you?
yes, very frequently ☐ ☐ ☐ ☐ ☐ no, hardly ever
If yes, which

(7) Did the lecturer presuppose knowledge that could not be expected at this stage?
yes, very frequently ☐ ☐ ☐ ☐ ☐ no, hardly ever
If yes, which

(8) Were the treated topics sufficiently motivated and well explained?
yes, always ☐ ☐ ☐ ☐ ☐ no, hardly ever
Which motivations and explanations did you particularly like/dislike?

Course Presentation:

(9) Was the medium for presentation (blackboard, overhead projector, etc.) adequately used?
yes, very much ☐ ☐ ☐ ☐ ☐ no, not at all
If no, comment

(10) Did the lecturer strive for a dialogue with the audience?
yes, very much ☐ ☐ ☐ ☐ ☐ no, not at all

Tutorials:

(11) Did the problems posed aid you in your understanding of the course material?
yes, very much ☐ ☐ ☐ ☐ ☐ no, not at all
If no, why?

(12) Were the problems clearly formulated?
yes, very much so ☐ ☐ ☐ ☐ ☐ no, not at all

(13) What amount of time did you spend on doing the problems?
for a one hour tutorial:
much more than 4 hours ☐ ☐ ☐ ☐ ☐ much less than 4 hours

for a two hour tutorial:
much more than 8 hours ☐ ☐ ☐ ☐ ☐ much less than 8 hours

(14) Was/were the tutor/s able to identify and remove your difficulties with the problems?
yes, very much so ☐ ☐ ☐ ☐ ☐ no, not at all
If no, comment

Room for Additional Remarks

PROBLEM SOLVING AS A PROBE FOR EXAMINING THE EPISTHEMOLOGICAL OBSTACLES IN THE PHYSICS UNDERSTANDING

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Abstract:

The purpose of this article is to draw attention of the physics teachers to difficulties which their pupils have when solving problems and to show that some of these difficulties reflect the episthemological obstacles which children have when learning, understanding or creating physics. It is illustrated on simple examples from kinematics. The reccomondations for school practice conclude the article.

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The paper is prepared for the International Symposium on the Evaluation of Physics Education. Criteria, Methods and Implications, Helsinki 1990.

Introduction.

A lot has been written about the solving problems by pupils, students, experts and novices. Nevertheless practical progress in schools seems to be rather moderate, if any. So old results in this field should be repeated and remembered, may be reformulated to be better understood by teachers. New research are needed and the better collaboration between science educators and teachers is absolutely necessary. I'd like to add my modest conrtibution to this field and to encourage the physics teachers to do their own investigations.

The examples presented in this paper have been chosen from others collected by me and physics teachers /1/. We are interested in difficulties which children (aged 10-16) have in situations in which from the first point of view they should not to have, it means, when they have enough mathematical skill, when situations or phenomena are familiar to them.

What kind of difficulties children have when solving problems, why they fail?

I Children are not interested in the given problems. If so, then often because they need solution for a good mark and in the peer competition. Children have different interests than adult scientists /2/. They concentrate on the rich small-scale structure of phenomena which is in opposition to the physicists approach. A solution of the given problem have no cognitive value for children. The result is easily forgotten.

II The majority of problems offered in schools are such that the solutions are "transforming formula-like". Such problems guide children to blind manipulation of formula. This phenomenon is known and widely describe /3/ (e.g. in /3/ Schecker calls it Formelfixirung"). Altough the strategy of fitting formũla is in majority of cases optimal and finishes with success, in many cases, in which problem is not typical and needs thinking, such a strategy fails.

III Very often, pupils, even with sufficient mathematical skills have difficulties in the transfer of mathematical notions to the description of reality /4/.

IV It happens, that altough the situation described in the problem is familiar to children, their "picture" of situation is overwhelmed by some preconception, or even misconception, by impression of the first observation, first understanding, or "anchoring intuition" /5/.

V Problem is too difficult for the developmental level of a child. Solution needs too many steps, too formalised calculations which cannot be done in the memory in one jump.

What can one learn by examining pupils solutions?

Let illustrate it on a simple, classical example:

The 14, 15 old pupils have been given the following problem:

From the village G to the city M (M well known to pupils) is the distance of 12 km. The car was driving from G to M in such a way that the first 6 km it had the constant speed 60 km/h, and the second 6 km only 20 km/h. What was the average velocity of the car on the distance G-M.

What can be the reason of the change of the speed of the car?
What do you imagine, how will the car cover the way back?

The problem was given to the 18 good Cracow pupils of the 8 th grade. Those pupils had rather formal, old fashioned mechanics course, one year before test was performed. Test was in stressing situation. 6 boys gave answer (20+60)/2=40. 5 of them are very good at mathematics. All of them, after remarks that they have been mistaken and after short time of reflection noticed the mistake themselves. Other children, in such a situation should be helped by order to calculate the total time of the travel. The rest of the group of good pupils gave correct answers.

20 country pupils (with good mathematics in school and physics unknown) gave in 50% such a wrong unswers. When problem was changed in such a way that the distance from G to M was divided into two pieces in the proportion 3:1 the number of wrong answers diminished, but the percentage of children who did not know how to solve the problem increased. In the very moment we do not have statistics big enough to present it, but the experienced country teacher raported this phenomemon as significant. Preliminary results from observations of children of age of 12-15 shows that children succeeded in solving this kind of problems when:

1/ the situation described in the problem is easy to be imagined, is familiar or similare to familiar situation. The question should create interest in the solution. (for example problem of escaping from the police, problem to be on time on bus station, problems from sport, problem about cosmonauts).

2/ data are simple enough for the calculation to be done in one jump in the memory.

Children fail often when:

1/ Problem is boring, problem is formulated in the formal way "The body m is mooving from G to M with the constant velocity..."

2/ numerical data are so complicated that children must perform written calculations. Then they run into blind application of known formula, which they apply at random, they apply mathematical operations also at random.

Discussion:

Kinematics is difficult. Notions involved as trajectory, velocity are from differential geometry. This notions include concepts of infinity, infinitezimal smalls. They are advanced mathematical notions, it took humanity hundreds years to discover them to make them familiar. For teachers they are no more abstract and are as familiar as if they were born with the knowledge of them. But children do not have need for them, they are not interested in introducing them. For children trajectory is a complicated structure (fractal like?) on which some vehicle is mooving. Children are interested how the body is mooving (on wheels, on legs, it rolls, shakes,...) and why it is mooving/4/. When we force children to neglect all these interesting them phenomena and we make them concentrate on the notion of trajectory, velocity - it is kind of violation on the nature of children. It is the role of a teacher to make this violation softer. First of all the teacher must create interest towards the problem, secondly by considering with children the variety of examples he must make children used to such problems. It must be done slowly. Children must be aware that they notice reality correctly, that their interests is also under the science consideration, but they must be postponed for future. They must be aware that a funny movement of flying object is also exciting for physics, but one must learn other things before.

What is the origin of the quoted mistake in the calculation of average velocity? This mistake comes from the automatical transfer of arithmetical average learned on mathematics lessons before. Arithmetical average is introduced in the 4 grade and is practiced on many examples. It seems to be well assimilated by children. Arithmetical average was the "first meeting" with the notion of average, it plays a role of "anchoring intuition". The notion of average velocity is new kind of average, namely harmonic average. It can later play a role of anchoring intuition, when properly understood. But that it could happen, children must jump episthemological obstacle. It should be practiced on many examples, spectacular examples of wrong calculation should be given. Good teachers always do that. The phenomenon of sticking to the first observation was seen in the pupils explanations of the possible reasons for the different velocity of the car /1/. Cracow is in a rather hilly surrounding and majority of pupils drow the picture like below. Their explanation has origin from the personal cycling experience. When we looked together at the given in problem data they have found other explanations.

Before the end of the article I will briefly describe the situation in which developmental level of pupils manifests very clearly. The pupils of different age from 9 to 15 have got the problem of Achilles and Tortoise /1/. Small children have been able to give an aproximately good answer and violently protested against having to follow the Greek thinking. They knew that Achilles had a hand and could catch the Tortoise. The notion of infinitely many steps seemed to be useless. Older students have been embarased by the problem. Although from the mathematics lesson they learned how to calculate the limit of the geometrical serie, the problem remained misterious for a long time. They saw the paradox. They have been in unequilibrium. They have to jump episthemological obstacle. Teacher should not force them to do it too fast. When dealing with young children teacher should not force them to jump over such an obstacle, when children do not see it. Formalization of the problem can be done, new formal definition can be introduced when children are familar with the problem, when they understand it in term of everyday language. They should have a need for a better description. Probably there are children, who are never able to take such a step. Such children should obtain science education in a limited range, with many experiments, in terms of everyday language. In the school practice too early formalization, too early use of precised physics language blocks the process of thinking and reflecting, for selfinvestigations. Instead, children repeat ready formula and phrases by heart.

Advice for teachers:

1/ Observe your pupils how they think, what is interesting for them.

2/ Do not force them to solve problems in stress situations /for grades, test/. At least not always.

3/ Discuss with them "wrong answers" without sharp critics, look for the reasons.

4/ Make the problems interesting for them, even at the cost of some time lost.

5/ Solve many simple, as divers as possible, examples in memory, use help of notebook only when there is a need of a extended memory (problem insolves steps). Later, teach children to take notes of solving problems by means of verbal comments, but only those who really need it.

6/ Remember that children have different interests, they construct different analogies, they have different associations. Look for "anchoring intuitions" which they have, find preconceptions. Observe what kind of impact have your examples.

7/ Remember that your students are not experts, they do not reach full developmental level, and although the experts way of solving is certainly the most efficient, but often not accessible for children.

8/ Prize your students not only for the good solutions but also for activity and creativity.

Literature:

/1/ Z. Golab-Meyer, preprint TPJU -D10/90 in preparation, in polish, "Why the concept of velocity is difficult?".

/2/ Z. Golab.Meyer, preprint TPJU D6/90, talk presented on Europhysics Study Seminar "Problems of Interactions Between Physics and Mathematics in Physics Education", Sobieszewo, April 1989, "The position of Mathematics in Teaching Physics - Looking for Difficulties in Physics Understanding".

/3/ review of many papers about this subject contains the dissertation of Horst Schecker :Das Schuelervorverstandnis zur Mechanik", Bremen 1985.
also M.Fialkowska, dissertation, Cracow WSP, 1979, in polish.

/4/ P. Guidoni, "Mechanics for Everybody", in "The Many Faces of Teaching and Learning Mechanics", proceedings of GIREP conference 1985, edited by P. Liljense.

/5/ John Clement, "Overcoming Students' Misconceptions in Physics, the Role of Anchoring Intuitions and Analogical Validity", proceedings of the Second International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, vol.III, Cornell University, Ithaca NY 1987.

COUPLING OF PHYSICAL SITUATION TO GRAPHICAL REPRESENTATION

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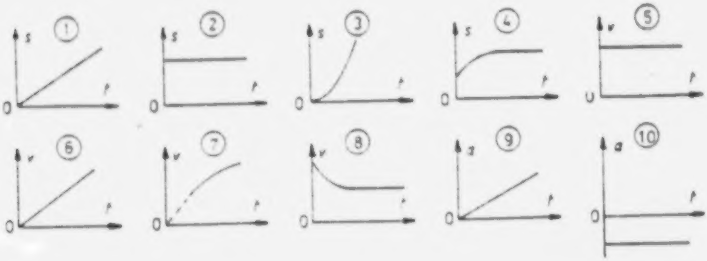
The understanding of graphs is an important skill to everybody. In physics, as in science generally, graphs are used for displaying data in a pictorial (concrete) form and for analysis of the behaviour and relationships of the variables. In basic math education, students learn about the coordinate system, how to plot the points and how to construct graphs of linear and more complicated functions. In physics, the emphasis should be in understanding the correspondence between the graphs and the real-life phenomena and the description of the real-life phenomena with the aid of the graphs, e.g. interpolation and extrapolation, noticing the changes in a graph and differences between graphs, prediction of relationships between variables and recognition of experimental laws and formation of new concepts.

Students are known to have difficulties to interpret graphs representing the one-dimensional motion of objects (Trowbridge and McDermott, 1980). According to Goldberg and Anderson (1989) there are many factors contributing to these difficulties including a lack of understanding of kinematic concepts and confusion between these but especially an inability to extract appropriate information from the slope or ordinate of a graph and a tendency to join the curve to the picture of the motion of the object.

This work is a part of a study of student understanding on graphical problems in Finnish national student examination. In an earlier study the students were given the problem including the position-time graph of motion where two objects move simultaneously along different paths. According to 43 % of answers the instantaneous velocity of the objects is the same at the intersection of the lines i.e. when the objects are at the same position (Ahtee *et al.*, 1985).

The problem studied in this work is as follows:
The following diagrams represent the position, velocity and acceleration of an object versus time in a Cartesian plane at rest

in relation to the Earth. Which of the graphs are connected to the cases below:
a) a parked car b) a person standing on a moving staircase c) a train arriving to the station with uniform decceleration d) a tram leaving the stop with uniform acceleration e) a person descending with the aid of a paraschute f) a car accelerating with constant power?
One or more graphs can be attached to each case. The number of the diagram is enough for an answer.



The cases a and b are straightforward and easy. However, in the latter case two diagrams (1 and 5) are demanded. The cases c and d are different variations of the same type of motion even that the corresponding diagrams are fairly different. As the correct answer in the case c we accepted (because of the fairly loose wording of the problem) either the diagram 4 alone or the diagrams 4 and 10 together but in the case d both the diagrams 3 and 6 had to be given. In the cases e and f the students have, first, to understand the physical situation and secondly recognize the correct diagrams. In these cases we marked in the analysis the points only according to whether the students had understood the physical situation i.e. found the correct choice (e8 and f7, correspondingly) without taking into account the other diagrams which they had – plenty and wrongly – included in their answers.

For the analysis, we checked 25 schools consisting of 445 students from which 103 were girls. Only those students were taken into account who had taken the longer course in physics and were taking the so called modern subjects (religion, psychology, history, science and geography) as an extra voluntary item in the student examination. The grouping can be considered as representative as the mean of the points from this question, 3.81, is the same in the studied group as obtained by all students – the question was marked from 0 to 6 points.

In Table 1 are collected the propositions in per cents of the correct answers. Approximately two thirds of the answers in the cases a and b were correct. In addition, in about 10 % of the answers the constancy of acceleration (diagram 10) was included. In this case the tension of the test situation and carelessness may also have affected so that diagram 10 was taken to represent the case $a = 0$. In the case a also the constancy of velocity was offered (diagram 5) as well as in the case b, where also the constancy of position (diagram 2) and/or the uniform increase in velocity or acceleration (diagrams 6 and 9) were included.

Table 1. The proportions in per cent of the correct answers.

	a	b	c	d	e+	f+	N
all	65	62	47	40	32	40	445
girls	62	60	33	28	20	23	103
boys	66	63	51	43	35	45	342

The cases c and d are clearly more difficult than the cases a and b, especially the girls have succeeded less well – only one third of the girls have found the correct solution. The wording of the problem gives the possibility to the interpretation that also diagram 10 in addition to diagram 4 is acceptable. In about 15 % of the answers diagram 10 – only part of the solution – was offered, and in about 10 % of the answers diagram 8. In the case d diagram 6 was found in 75% of the answers and diagram 3 in about 60 %. In about 10% of the answers other diagrams were offered in addition to the diagrams 3 and 6, especially the uniform increase in acceleration (diagram 9).

The percentages in the cases e and f do not correspond the amount of correct answers. The main point in the analysis of these cases was to find out how many of the students, on the whole, had understood the physical situation. However, when the pure number is given as an answer without the reasoning behind it, it is probable that there are answers based on wrong arguments.

Again in these cases the girls have succeeded clearly less well than the boys. In the case e one third of the boys have found the correct diagram but only one fifth of the girls. In 40% of the answers only the fall with the final constant speed was taken into account (diagrams 5 and/or 1). Also the negative constant acceleration (diagram 10) – the effect of gravity? – was offered fairly abundantly in about 10% of the answers.

In 40% of the answers diagram 7 had been found. In almost every fourth answer diagram 3 was offered as well as the explanation that velocity would increase uniformly during the whole motion. In every third answer it was claimed that also acceleration increases uniformly.

As a conclusion, it can be said that much more attention should be paid to interpreting and connecting the graphs with the real-life events. Especially the girls seem to have learnt the physical content superficially. The students have to be explicitly led to connect the graphs with actual motions, e.g. by giving them a set of (t,s), (t,v) and (t,a) graphs and asking them to carry out the corresponding motions themselves and to give verbal interpretations of the diagrams and compare different sets of diagrams etc. Also the reverse excercises are important, i.e. to sketch the (t,s), (t,v) and (t,a) diagrams of the real motions e.g. of a runner or rolling balls.

A powerful tool nowadays available for one-dimensional motion is the microcomputer-based laboratory device based on a sonic-pulse transmitter and receiver (Thornton, 1987).

References

Ahtee, M., Ahtee, A. and Forsblom, K.I.C. (1985). Understanding of the concept of velocity in the Finnish student examination. (in Finnish). MAA **49**(2), 147 – 152.

Goldberg, F.M. and Anderson, J.H. (1989). Student difficulties with graphical representations of negative values of velocity. Physics Teacher **27**(4), 254 – 260.

Thornton, R.K. (1987). Tools for scientific thinking: Microcomputer based laboratories for physics teaching. Phys.Educ. **22**, 230-238.

Trowbridge, D. E. and McDermott, L. E. (1980). Investigation of student understanding of the concept of velocity in one dimension. Am. J. Phys. **48**(12), 1020 – 1028.

USE OF STROBOSCOPIC AND VIDEOCAMERA IN STUDYING TWO-DIMENSIONAL MOTION

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The physical concept formation is in principle a Gestalt perception process. It starts with recognition of and giving name to observable features (Gestalts) in the surrounding nature. Then it is followed by the identification of variables i.e. effects which can be measured and conditions which should be changed or kept constant. The experimental law is simply a way to classify the behaviour of the phenomenon but it is also a starting point in forming new concepts.

The graphical representation is the simplest way to describe the changes in the dependent variable, However, the students have considerable difficulties both in connecting graphs to physical concepts and to the real world (McDermott *et al.*, 1987). Therefore, it seems important to pay special attention from the very beginning to the representation of real-life phenomena with the aid of the graphs and vice versa. As Arons (1990) says: "Unless they are explicitly led to do so, however, the students do not consciously connect the graphs with actual visualized motions; they treat them as uninterpreted abstractions."

Timer and photogate systems are amply used at school for determining one-dimensional motion. Timer marks points on a paper slip connected to the moving object in 1/50 or 1/100 s intervals. In Figure 1a and b the (t,s) and (t,v) diagrams are plotted from the measurement where a runner starts from the rest and takes a few steps. The (t,v) diagram shows that the velocity is not increasing evenly but decreases when the body rotates around the leg in front. By comparing the two diagrams the length and duration of the steps can be measured.

Both timer and photogate systems are fairly inconvenient to use in studying the real motions of the students themselves. A powerful tool now available for one-dimensional motion is the microcomputer-based laboratory device of the sonic range finder which exhibits graphs of (t,s), (t,v) and even (t,a) directly on the computer screen of motions executed also by the student himself

(Thornton, 1987). However for the studies of two-dimensional motion some other kind of registration is needed.

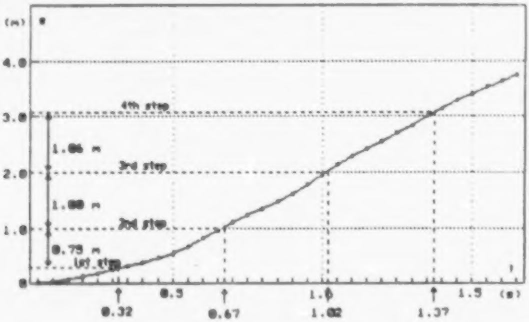

Fig. 1a. Distance travelled by a runner as a function of time.

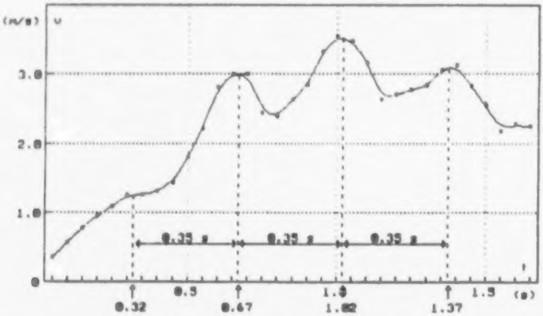

Fig. 1b. Speed of a runner as a function of time.

In studying two-dimensional motion on an air-table we have used stroboscopic camera. A rotating disc with two holes is mounted in front of the camera. The exposure time can be changed by adjusting the rotation time.

The slides were reflected on the wall and from these pictures the positions of the moving bodies were measured. Scaling was obtained from the ruler always included in the photos. In Figure 2 the motion of the centre of mass of the two bodies fixed together is shown. For more accurate purposes an electromechanical device have been designed with the aid of which the initial velocity of one of the moving bodies can be adjusted and so determine before hand the nature of the motion (Andersson, 1990). Of course, with the aid of the stroboscopic camera also the analysis of the motions of the students themselves can be carried out.

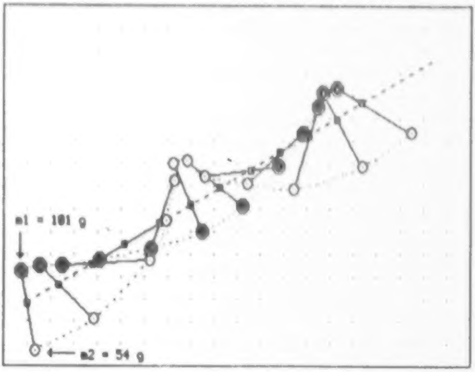

Fig. 2. Motion of the centre of mass of two bodies fixed together.

A videocamera may, however, suit better for school situation even that the picture obtained with the aid of it is not as accurate as the one taken with an ordinary camera. Also the time interval between the successive pictures is not always the same as the time between different sweeps depends on the position of the object and the camera. Also the lens aberrations increase near to the edge of the picture. On the other hand, one does not need to develop the film to see whether the measurement has succeeded. The tape can be looked immediately after and repetition of the experiment can be renewed if needed. Furthermore, the motions can be studied in detail using slow motion, advancing frame by frame and zooming. In Figure 3 is shown the results from an elastic collision of two pucks, the other being initially at rest. The analysis was made straight from the TV-screen.

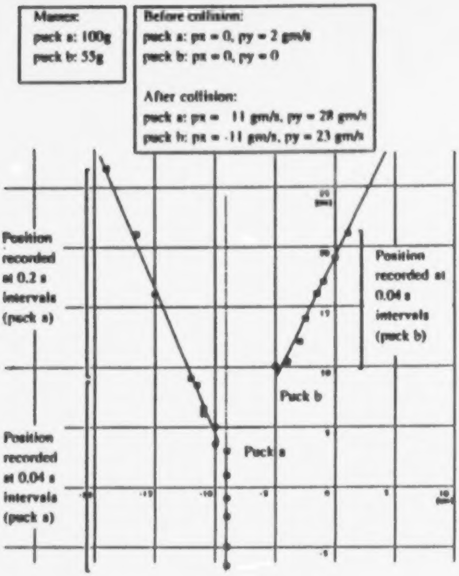

Fig. 3. Analysis of the elastic collision between two pucks, the other initially at rest.

References

Andersson, S. (1990). Demonstration of the initial value problem in mechanics. Master's thesis (in Finnish). Department of Physics, University of Helsinki.

Arons, A. (1990). *A Guide to Introductory Physics Teaching*. John Wiley & Sons, New York.

McDermott, L. C., Rosenquist, M. L. and van Zee, E. H. (1987). Student difficulties in connecting graphs and physics: Examples from kinematics. Am. J. Phys. **55** (6), 503-513.

Thornton, R. K. (1987). Tools for scientific thinking: Micro-computer based laboratories for physics teaching. Phys. Educ. **22**, 230- 238.

ELECTRICITY'CONCEPTS IN PRIMARY SCHOOL

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Primary school children enjoy and appreciate scientific ideas and activities. In the poster are sketched some examples of activities which have been used to lead primary school pupils (from grade 1 to grade 5) to a first idea of the working of Science: the examples deal with electicity'concepts like current and voltage.

In fig. 1 it is shown the device the children used to work (each pupil had his own).

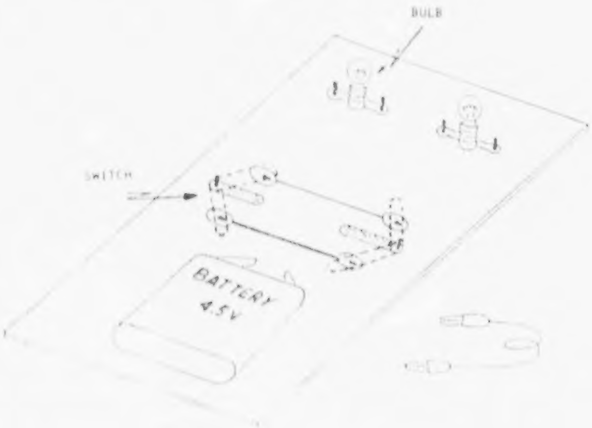

Figure 1

Starting point: the children are required to connect one bulb to the battery; a closed path is obtained and the bulb lights up. In order to light up two bulbs together two closed paths are possible but bulbs'lightness is different.

Inquiring work: two bulbs in series are connected with the battery and using the switches, all the closed paths, dealing with bulbs shining, . are obtained (in fig. 2 an example is shown).

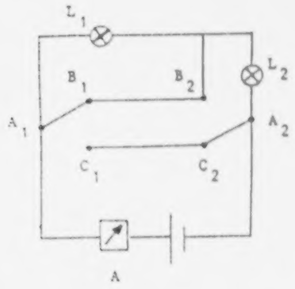

Figure 2

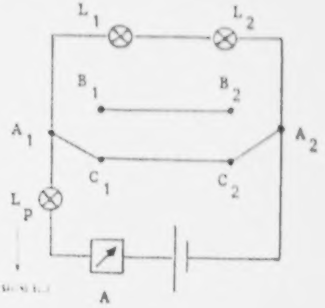

Figure 3

The proofs are then repeated connecting the bulbs in parallel.

Results (first idea of current): it is possible, using the switches, turn on the current and divide it to flow through different parts, at the same, and then reunite.

Current'values in a closed circuit are measured using an Ammeter (see fig. 3); the results (current's concept): in a closed path the current is the same as after each component as before.

Where a circuit branches, the sum of the currents in the branches is the same as the current in the main wire.

Examples of activities used to lead the children to voltage's idea. In a closed path where bulbs of different kinds, in series, are connected with the battery, the current is flowing (Ammeter is reading), the bulbs light up and the working voltage of battery (Voltmeter is reading) V_C is less than battery voltage V_B. The working voltage V_{Bi} (Voltmeter is reading) of the bulbs of different kinds are different and each one is less than V_C, but the sum of the V_{Bi} is the same as V_C.

The proofs have been repeated using a circuit where the bulbs are in parallel.

If the circuit is interrupted, there is no flowing current, no bulbs'shining; the voltage of the battery is V_B, all V_{Bi} are zero, put at the break the voltage is V_B.

Results of quantitative proofs: in a closed circuit the current'values depends on the kinds of the bulbs used, the way they are connected and the battery voltage.

Technical application also had a part: a two poles switch has been built and its working has been studied. (Fig. 4).

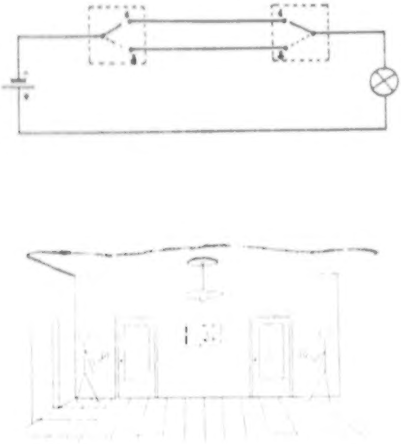

Figure 4

ON THE INTEGRALITY OF ORBITAL ANGULAR MOMENTUM QUANTUM NUMBERS

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Abstract: A simple constructive proof of the integrality of orbital angular momentum quantum numbers is given.

I. Introduction

As a rule, textbooks on Quantum Mechanics derive the integrality of orbital angular momentum quantum numbers as a consequence of the (assumed) single-valuedness of the relevant wave-functions in coordinate space. Such derivations are frequently supplemented with comments concerning the incompleteness of arguments based on single-valuedness of wave-functions, together with footnotes referring to unpublished (and therefore unavailable) works by the pioneers of Quantum Mechanics in which the "correct" arguments are supposed to be found.

In this paper I present a simple proof of the integer nature of orbital angular momentum quantum numbers, which does not rely on assuming single-valuedness of wave functions. It is shown that the integrality of the quantum numbers follows by requiring that the orbital angular momentum operators have a realisation as self-adjoint operators in a linear vector space equipped with a natural rotationally invariant scalar product. The proof is conceptually simple and constructive, and does not require concepts other than those normally used in introductory courses on Quantum Mechanics.

II. The Angular Momentum Operator Algebra

The commutator algebra of quantum mechanical angular momentum operators is (in self-explanatory notation and in units where $\hbar = 1$),

$$\left[\hat{J}_k , \hat{J}_\ell\right] = i\epsilon_{k\ell m}\hat{J}_m . \qquad \text{(II.1)}$$

As is well known, the operators $\hat{J}_k$ can be realised as matrices on a set of states $|j,m>$, which are eigenstates of the operators $\hat{\mathbf{J}}^2$ and $\hat{J}_3$,

$$\hat{\mathbf{J}}^2|j,m> = j(j+1)|j,m> , \quad \hat{J}_3|j,m> = m|j,m> . \qquad \text{(II.2)}$$

Furthermore, it is a standard calculation to show that the quantum numbers j and m are simultaneously either integers or semi-integers,

$$2j = \text{non-neg. integer}, \quad m = \{-j, \ -j+1, \dots, \ j-1, \ j\}. \tag{II.3}$$

The abovementioned results are usually obtained with the aid of the step-operators $\hat{J}_{\pm}$,

$$\hat{J}_{\pm} = \hat{J}_1 \pm i\hat{J}_2 . \tag{II.4}$$

The step-operators act in a simple manner on the states $|j,m\rangle$,

$$\hat{J}_+ |j,m\rangle = \sqrt{(j-m)(j+m+1)} \ |j,m+1\rangle , \tag{II.5}$$

$$\hat{J}_- |j,m\rangle = \sqrt{(j+m)(j-m+1)} \ |j,m-1\rangle . \tag{II.6}$$

In particular, the highest state with $m = j$ satisfies the following equation,

$$\hat{J}_+ |j,j\rangle = 0 . \tag{II.7}$$

Likewise,

$$\hat{J}_- |j,-j\rangle = 0 . \tag{II.8}$$

An arbitrary state $|j,m\rangle$ with m in the range given in (II.3) can be obtained by operating with the appropriate step operator on the state with lowest (or highest) value of m. For instance, using Eq. (II.5) repeatedly one obtains,

$$|j,m\rangle = \sqrt{\frac{(j-m)!}{(j+m)!(2j)!}}\,(\hat{J}_+)^{j+m}\ \ |j,-j\rangle \qquad (II.9)$$

The results presented above (or equivalent results, involving different phase conventions) can be found in almost any textbook on Quantum Mechanics. As is known, these results follow directly from the commutator algebra satisfied by the operators $\hat{J}_k$ together with the assumption that the states $|j,m\rangle$ span a linear vector space equipped with a Hermitian inner product which defines a non-negative definite norm.

III. Orbital Angular Momentum Operators

Consider the basic position- and momentumoperators $\hat{\mathbf{r}}$ and $\hat{\mathbf{p}}$, respectively. Their fundamental commutators are (still in units where $\hbar = 1$),

$$[\hat{r}_k\ ,\ \hat{p}_\ell] = i\delta_{k\ell}\ . \qquad (III.1)$$

The orbital angular momentum operator $\hat{\mathbf{L}}$ is then,

$$\hat{\mathbf{L}} = \hat{\mathbf{r}}\times\hat{\mathbf{p}}\ , \qquad (III.2)$$

or, in component notation,

$$\hat{L}_k = \varepsilon_{k\ell m}\,\hat{r}_\ell\hat{p}_m \qquad (III.3)$$

The orbital angular momentum operator components $\hat{L}_k$ satisfy the commutator algebra (II.1) of the general operators $\hat{J}_k$ and therefore all the previous results following from the angular momentum operator algebra are a priori valid for the orbital angular momentum operators as well. However, one might obtain further restrictions by considering a particular realisation of the angular momentum operators. It will be shown next that the integer nature of the orbital angular momentum quantum numbers follows precisely from the requirement that these operators have a realisation in coordinate space.

IV. Coordinate Space Realisation

Consider now the coordinate-space realisation of the momentum operator $\hat{\mathbf{p}}$ ($|\psi\rangle$ is an arbitrary state),

$$\langle\mathbf{r}|\hat{\mathbf{p}}|\psi\rangle = \int d^3\mathbf{r}' \, \langle\mathbf{r}|\mathbf{p}|\mathbf{r}'\rangle\langle\mathbf{r}'|\psi\rangle \, , \qquad \text{(IV.1)}$$

Using the matrix-elements,

$$\langle\mathbf{r}|\hat{\mathbf{p}}|\mathbf{r}'\rangle = -\, i\nabla_{\mathbf{r}}\, \delta^3(\mathbf{r} - \mathbf{r}') \, , \qquad \text{(IV.2)}$$

one obtains,

$$\langle\mathbf{r}|\hat{\mathbf{p}}|\psi\rangle = -\, i\nabla \, \langle\mathbf{r}|\psi\rangle \, , \qquad \text{(IV.3)}$$

which is usually expressed as an operator correspondence,

$$\hat{\mathbf{p}} \leftrightarrow - i\nabla . \qquad \text{(IV.4)}$$

In the sense of the operator realisation above, there is also the correspondence,

$$\hat{\mathbf{L}} \leftrightarrow \mathbf{L} \equiv - i\,\mathbf{r}\times\nabla . \qquad \text{(IV.5)}$$

Using the operator realisation (IV.5), the eigen-value conditions (II.2) translate into the following differential equations (we use the notation $|\ell,m\rangle$ for the orbital angular momentum eigen-states),

$$-(\mathbf{r}\times\nabla)^2\langle\mathbf{r}|\ell,m\rangle = \ell(\ell+1)\langle\mathbf{r}|\ell,m\rangle \; , \; (\mathbf{r}\times\nabla)_3\langle\mathbf{r}|\ell,m\rangle = im\langle\mathbf{r}|\ell,m\rangle \qquad \text{(IV.6)}$$

As is known, the equations (IV.6) simplify considerably in spherical coordinates,

$$\mathbf{r} = r(\sin\theta\cos\phi,\ \sin\theta\sin\phi,\ \cos\theta) \qquad \text{(IV.7)}$$

In fact, the equations (IV.6) are independent of the radial variable r, which means that the transition functions $\langle\mathbf{r}|\ell,m\rangle$ depend on r in a trivial (factorisable) way. For purposes of normalisation, one may include a (normalisable) function of r in the expression for the functions $\langle\mathbf{r}|\ell,m\rangle$, but one may equally well omit the integration over r in the normalisation condition for these functions, which then reads as follows,

$$\int_0^{2\pi} d\phi \int_0^{\pi} d\theta \sin\theta \,\langle\ell',m'|\mathbf{r}\rangle\langle\mathbf{r}|\ell,m\rangle = \delta_{\ell'\ell}\,\delta_{m'm} \qquad \text{(IV.8)}$$

The expression (IV.8) can be considered to define the natural rotationally invariant inner product for the functions $<\mathbf{r}|\ell,m>$.

The second equation in (IV.6) reads as follows in spherical coordinates,

$$\frac{\partial}{\partial\phi}<\mathbf{r}|\ell,m> = im<\mathbf{r}|\ell,m> , \qquad (IV.9)$$

so that

$$<\mathbf{r}|\ell,m> = e^{im\phi}\, F_{\ell,m}(\theta) . \qquad (IV.10)$$

where the functions $F_{\ell,m}$ are to be determined.

Rather than solving the remaining differential equation for the functions $F_{\ell,m}$ we will use equations corresponding to the equations (II.8) and (II.9) which gives all the functions $<\mathbf{r}|\ell,m>$ in terms of just one of them, namely $<\mathbf{r}|\ell,-\ell>$. For this purpose we still need the coordinate-space realisations of the step-operators $\hat{L}_\pm$. In spherical coordinates we have,

$$L_\pm = e^{\pm i\phi}\,(\pm\,\partial_\theta + i\cot\theta\,\partial_\phi) . \qquad (IV.11)$$

Using the equation corresponding to (II.8), viz.

$$L_-\,<\mathbf{r}|\ell,-\ell> = 0 , \qquad (IV.12)$$

as well as the expression (IV.10) for the case $m = -\ell$, one obtains a simple differential equation, namely

$$\left(\frac{d}{d\theta} - \ell\cot\theta\right) F_{\ell,-\ell} = 0 . \qquad (IV.13)$$

The normalised solution of Eq. (IV.13) is,

$$F_{\ell,-\ell} = \sqrt{\frac{\Gamma(2\ell+2)}{2^{2\ell+1}\Gamma^2(\ell+1)}}\,(\sin\theta)^{\ell}\,, \qquad \text{(IV.14)}$$

where Γ denotes Eulers gamma-function. Using the coordinate-space version of Eq. (II.9) together with the explicit expression for $\langle r|\ell,-\ell\rangle$ obtainable with the aid of Eq. (IV.14), one finally gets,

$$\langle r|\ell,m\rangle = C(\ell,m)\ (\sin\theta)^m \left\{ \frac{d^{\ell+m}\,(\sin\theta)^{2\ell}}{d(\cos\theta)^{\ell+m}} \right\} e^{im\phi}\,, \qquad \text{(IV.15)}$$

where $C(\ell,m)$ is the following normalisation constant,

$$C(\ell,m) = \frac{(-1)^{\ell+m}}{2^{\ell}\,\Gamma(\ell+1)} \sqrt{\frac{(2\ell+1)\ (\ell-m)!}{4\pi\ \ (\ell+m)!}}\,. \qquad \text{(IV.16)}$$

So far we have obtained no new restrictions on the orbital angular momentum quantum numbers ℓ and m. In accordance with the results of the general angular momentum algebra these quantum numbers have to be simultaneously either integers or semi-integers. However, we have not yet made use of the coordinate-space equation corresponding to Eq. (II.8), *viz.*

$$L_+ \langle r|\ell,\ell\rangle = 0\,. \qquad \text{(IV.17)}$$

Inserting the explicit expression (IV.15) (with $m = \ell$) in the condition (IV.17) one obtains,

$$L_+ \langle r|\ell,\ell\rangle = 0 \Leftrightarrow \frac{d^{2\ell+1}}{d\cos\theta^{2\ell+1}} (\sin\theta)^{2\ell} = 0 . \tag{IV.18}$$

It is evident that the last relation in (IV.18) cannot be fulfilled unless ℓ is a non-negative integer. Thus the orbital angular momentum quantum numbers must be integers.

V. Summary and Discussion

The proof of the integrality of the orbital angular momentum quantum numbers given above, is perhaps lengthy compared to the usual "proofs", but this is because the proof actually involves the explicit construction of all the transition functions $\langle r|\ell,m\rangle$. The proof given here clearly demonstrates why the orbital angular momentum quantum numbers can only be integers; otherwise the approprtiate (unitary) transition functions to coordinate space (and thereby the Hermitian coordinate-space realisations of the orbital angular momentum operators themselves) would not exist. We have thus recovered the proper reason for the integrality of orbital angular momenta. Actually, already in Dirac's classical text-book on Quantum Mechanics(1), there is a very brief comment in connection with the discussion of orbital angular momenta, which can be taken to mean that it is the very existence of a coordinate representation which forces orbital angular momenta to be integers (as contrasted to spin angular momenta). However, Dirac's argument uses effectively the single-valuedness of the transition functions, which by no means is obvious a priori. For instance, this question has been the subject of a rather lengthy analysis by Pauli in an article(2) which was published long after the first (and second) edition of Dirac's text-book had appeared in print. The result of Paulis analysis is that the transition functions ought to be single valued, but this was by no means self-evident, but essentially the consequence of requirements of square-integrability of the appropriate wave-functions. The proof given in the present paper differs considerably from the argumentation in Paulis paper, but is not altogether a novel one either; in the course of working it out I discovered a paper by J. D. Louck(3) containing a discussion of the question of the special nature of orbital angular momentum, which in substance is the same as the argumentation given in the present paper.

References

1) P. A. M. Dirac, "The Principles of Quantum Mechanics", (First Edition 1930) Fourth Edition, Oxford University Press 1958, Oxford.

2) W. Pauli, "Über ein Kriterium für Ein- oder Zweiwertigkeit der Eigenfunktionen in der Wellenmechanik", Helv. Phys. Acta **12**, 147 (1939).

3) J. D. Louck, "Special Nature of Orbital Angular Momentum", Am. J. Phys. **31**, 378 (1963).

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ON THE TEACHING OF THE CONCEPT OF ENERGY AT THE UPPER SECONDARY SCHOOL

The concept of energy and its teaching is one of the most important issues in the didactics of Physics. We can see it when we read curriculum studies, textbooks and didactic journals (e.g. Duit 1986). In addition to importance in natural science, energy has also a great social and economic significance.

At the lower levels at school energy must be taught with concrete methods according to pupils' developmental level. At the upper secondary school, when pupils are at the developmental stage of formal operations (Shayer & Adey 1981), we ought to take into consideration the abstractivity of the energy concept. Energy, as a physical concept in general, has an abstract nature. Many studies (e.g. Duit 1986; Jenelten-Allkofer 1979) show that this is difficult to pupils. The concrete and material nature is continuously present, as well as alternative frameworks of the concept of energy.

The definition of energy most frequently used in the teaching of physics is that energy is the ability to work. However, this definition is too limited because, for example, the nature of energy as heat should also be considered. According to Duit (1986, 1987), thermodynamics must receive more attention when teaching energy, and many researchers emphasize the central role of the law of the conservation of energy. There is a lot of didactic literature on teaching the concept of energy, and a considerable collection of these publications can be found in the sources of Duit's book (1986). In general, it is important to teach pupils according to their developmental stages, in a varied, spiral-like manner. Like in all teaching, also in the teaching of energy the constructive theory of learning (e.g. Watts and Pope 1989; Trumper 1990) is becoming more emphatic. This theory is, to a large extent, based on Piaget's theory (Sinclair 1990). Kubli (1987 and 1989), on the other hand, emphasizes the importance of emotional factors in teaching.

For many years I have carried out the study of practicability of the experimental-inductive method in Physics teaching at the upper secondary school level (Seinelä 1987 and 1988). The experimental-inductive method was developed by Börje Ekelund (Ekelund 1976, 1989). This method is concerned with the definition of physical concept. The experimental-inductive method is based on Jean Piaget's theory, which is primarily regarded as a theory of knowledge. Piaget's theory is concerned with both the structure of knowledge and how knowledge is structured in a young person. The two are closely connected. Piaget's view of knowledge is genetic, structuralistic and constructive.

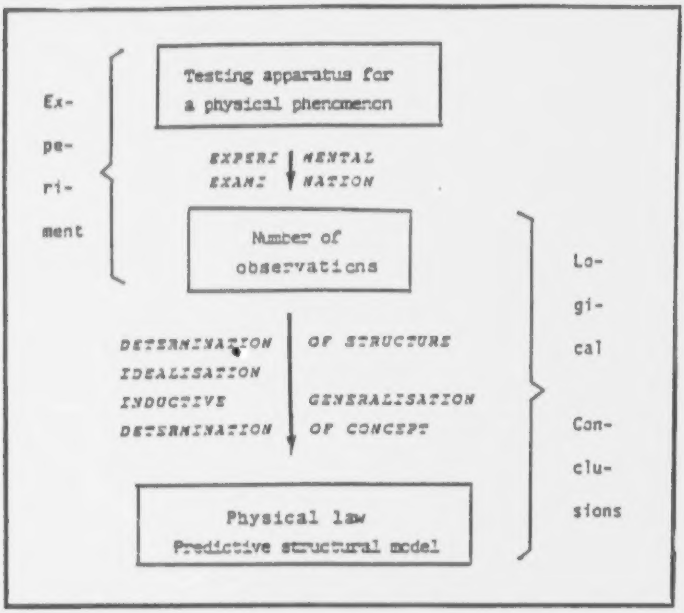
In the experimental-inductive method you start form the experimental basis and continue with the help of logico-mathematical conclusions. The definition of a concept is based on the invariance observed in the structure of the phenomenon (see Kubli 1979). A physical law precedes a definition, and a physical law is the structural model for a physical phenomenon (appendix). In the experimental-inductive method the theory of knowledge is emphasized, for example, the genesis of knowledge, structure, predictability and area of validity. In the co-ordination of the experimental-inductive method with the didactics of Physics the central focus is on the interaction between induction and deduction, which have to create a non-conflicting entity. Teaching, however, is started from the phenomenon itself, on an empirical basis. The pupils' own activity is important and, generally, the discovery learning type teaching; formality in teaching is avoided as much as possible. When applying the method, it should be used flexibly and purposefully in the teaching of Physics. The experimental-inductive method is best suited to the beginning of large teaching entities, such as mechanics, electricity, acceleration, force, work, *energy* and magnetic flux density. My experiments have shown positive results of the practicability of the method, within the limitations presented.

As an example of my studies I present main issues in the teaching of the concept of energy using the experimental-inductive method.

The method is question is intended for the Upper Secondary School level

- A phenomenon, for example an electric power plant in a waterfall
- Proceeding from a natural phenomenon to one in a laboratory, for example demonstrations of the falling motion
- Carrying out experiments on the falling motion, and, based on the experimenting, prove invariance
- The constant is defined as mechanical energy
- Similar cases are dealt with, for example the energy of rotation and the energy of a stretched spring
- Based on several individual cases, students arrive at the general conclusion of the law of conserving mechanical energy
- A general concept of energy concerning the whole field of Physics is a common term for all the carefully induced laws of energy.

Appendix


Ex-
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ment
Testing apparatus for
a physical phenomenon
EXPERI MENTAL
EXAMI NATION
Number of
observations
DETERMINATION OF STRUCTURE
IDEALISATION
INDUCTIVE GENERALISATION
DETERMINATION OF CONCEPT
Physical law
Predictive structural model
Lo-
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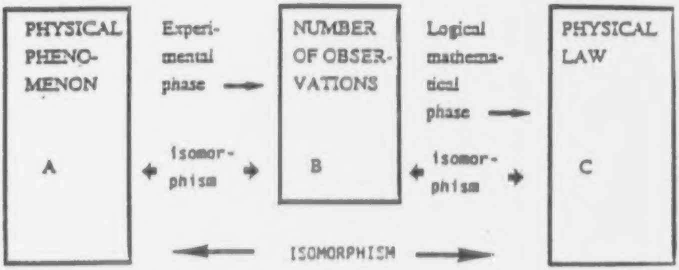
ISOMORPHISM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PHYSICAL
LAW
C
ISOMORPHISM

The experimantal-inductive method (Ekelund 1989)
(N.B. These formulas are not meant for pupils' use)

References

Duit, R. 1986. Der Energibegriff im Physikunterricht. Kiel: Institut für die Pädagogik der Naturwissenschaften and der Universität Kiel.

Duit, R. 1987. Der zweite Haputsatz der Thermodynamik — ein Thema für alle Schulstufen. Naturwissenschaften im Unterricht. Physik/Chemie. Heft 24, 4—10.

Ekelund, B. 1976. Fysikaliska Modeller. Åbo: Meddelanden från stiftelsens för Åbo Akademi forskningsinstut, Nr 10.

Ekelund, B. 1989. Tröghet, kraft, energi och attraktivitet. Kognitivt stringent framställning av elementär dynamik. Åbo: Åbo Akademis förlag.

Jenelten-Allkofer, C. 1979. Energievorstellungen von 5 bis 16 jährigen bei physikalischen Experimenten. Dissertation. Christian-Albrechts-Universität zu Kiel.

Kubli, F. 1979. Piaget's Cognitive Psychology and its Consequences for the Teaching of Science. European journal of science education vol. 1, no. 1, 5—20.

Kubli, F. 1987. Intresse und Verstehen in Physik und Chemie. Köln: Aulis Verlag Deubner & Co KG.

Kubli, F. 1989. Piaget's contribution to science education. Kouluhallitus 2/1989. Meisalo, V. & Kuitunen, H. (toim.) Nordic conference on science and technology education: Innovations in the science and technology education.

Seinelä, K. 1987. Kokeellis-induktiivisen menetelmän toimivuus lukion ensimmäisen luokan fysiikan opetuksessa. Piaget'n teoriaan perustuva tutkimus. Helsingin yliopiston opettajankoulutuslaitos, tutkimuksia 47. (Practicability of the experimental-inductive method in Physics teaching at the first-year upper secondary school level. A Piaget-based study. Academic dissertation. Research Report 47. The Department of Teacher Education. University of Helsinki.)

Seinelä, K. 1988. Kokeellis-induktiivisen menetelmän soveltaminen ja koordinointi lukion fysiikan kurssiin. Helsingin yliopiston opettajankoulutuslaitos, tutkimuksia 65. (The application and co-ordination of the experimental-inductive method to the Physics course in the upper secondary school. The Department of Teacher Education, Helsinki University. Studies 65.)

Shayer, M. & Adey, P. 1981. Towards a Science of Science Teaching. London: Heinemann Educational Books.

Sinclair, H. 1990. Learning: The Interactive Recreation of Knowledge. Steffe, L. & Wood, T. (eds.) Transforming Children's Mathematics Education, International Perspectives.

Trumper, R. 1990. Energy and constructivist way of teaching. Physics education vol. 25, no. 4, 208—212.

Watts, M. & Pope, M. 1989. Thinking about thinking, learning about learning: constructivism in physics education. Physics education vol. 24, no. 6, 326—331.

AN ANALYSIS OF EXERCISES IN FINNISH SECONDARY SCHOOL PHYSICS TEXTBOOKS

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The tradition of teaching physics in the Finnish secondary school has emphasized chalkboard physics and lecturing, with only few demonstrations. Most demonstrations have given the pupils little possibilities for active participation. The textbooks have also reflected the passive role of pupils in practical work. The exercises have been almost exclusively of mathematical nature. Demands for rapid change in the general approach of physics teaching have led to an interesting effort within the FINISTE network to activate new pedagogical approaches. Internationally there has been new interest in the analysis of textbooks even in the field of school physics.

In the present paper eight Finnish textbooks (Table 1) for the "major course" of Physics (about 250 teaching hours) printed between 1957 and 1989 are analysed by classifying the exercises of different content areas.

Table 1

A. Nurmi, U., Ahlman, G., Fedosow, J., Höglander, A., Qvickström,R.: Lukion fysiikka. Vol.1 (1957) (117-172) and Vol.2 (1960), (9-60, 167-179). WSOY
B. Kattainen,P.: Fysiikan oppikirja lukioluokille. Vol.I (1961), (100-108, 114-123, 153-187) and Vol. II (1961), (70-126, 173-183). OTAVA
C. Hyyti,S,. Nikkola,J,. Viljanmaa,L.: Fysiikka 10 (1973), (62-106), Fysiikka 11 (1976), (105-164) and Fysiikka 12 (1975), (28-52). KIRJAYHTYMÄ
D. Glad,S., Almkvist,G., Beskow,G., Knave,E., Hämäläinen,R., Ketolainen,P., Kälviäinen,J.: Fysiikan perusteet Vol.1 (1978), (86-135), Vol.2 (1978), (72-87, 119-211, 219-222) and Vol.3 (1979), (120-168). OTAVA
E. Kaukiainen,M,. Laurikainen,K.V., Toivanen,P., Vironseppä,A.: Uuden lukion fysiikka, laaja oppimäärä Vol.1 (1982), (100-153), Vol.2 (1983), (82-162) and Vol.3 (1984), (104-138). WSOY
F. Kurki-Suonio,K., Kervinen,M., Korpela,R.: Kvantti, fysiikan laaja oppimäärä Vol.1 (1982), (162-229), Vol.2(1983), (143-261) and Vol.3a (1984), (222-276). WEILIN & GÖÖS
G. Nikkola,J., Viljanmaa,L., Virtanen,T.: Laaja fysiikka Vol.I (1985), (118-184), Vol.II (1986), (99-206) and Vol. III (1985), (155-200). KIRJAYHTYMÄ
H. Erätuuli,M., (Korhonen,P.), Meisalo,V., Suokko,E.: Fysiikan maailma Vol.1 (1987), (129-201), Vol.2 (1988), (101-220) and Vol.3 (1989), (139-200). OTAVA

Three different content areas were selected for the present stydy: 1. Thermodynamics,
2. Electric and Magnetic Fields and DC Circuits,
3. Nuclear Physics.

These areas were relatively easy to identify in each book.

The categories of exercises are outlined in the next table:

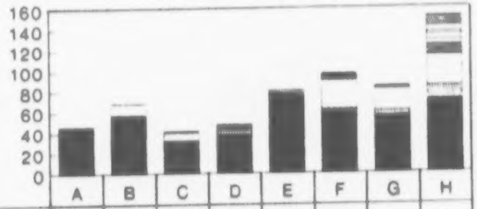
Table 2

1. Ordinary mathematical exercises of the type "calculate..." or "determine...".
2. Graphical exercises of the type "draw...", "determine from the diagram..." etc.
3. Logical exercises of the type "explain, how...", "make inferences on...", "evaluate..." etc.
4. Tasks of finding information in the literature.
5. Experimental tasks of the type "study experimentally...", "measure..." etc., intended mainly to be done at home.
6. Practical tasks of the type "plan...", "construct and study..." or "develop new ways of...".
7. Lesson exercises, which are mainly of experimental nature.
8. Other types of exercises, e.g. "show, that...", "write the equation for...", "derive a mathematical expression for...". These are often of mathematical nature.

It is not always easy to find unanimously the correct category for each exercise, but two independent classifiers had little differences in the distributions. Some exercises have parts belonging to different categories. Multiple choice questions are included in the relevant categories.

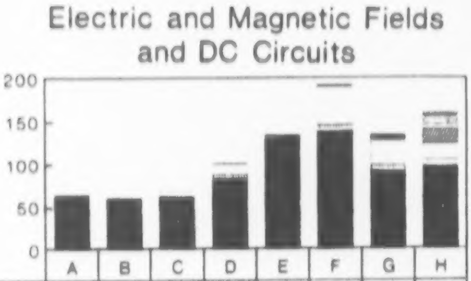
Thermodynamics

Diagram 1



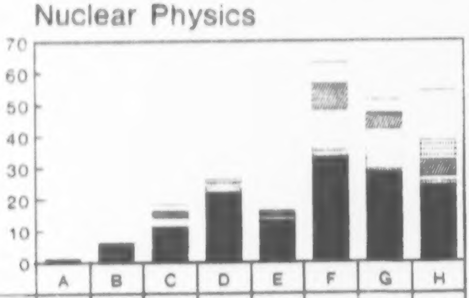
	A	B	C	D	E	F	G	H
8 Other ☐	1			2		2	1	2
7 Lesson exercises ▨								8
6 Plan ☐						1		5
5 Study/experiment ▨						1		13
4 Find out ▨			1	2		2	1	10
3 Make inferences ☐		11	8	2		28	21	30
2 Draw ▨	1		2	4	3	2	5	13
1 Calculate ■	44	57	30	37	77	60	55	70

Diagram 2



		A	B	C	D	E	F	G	H
8 Other							1	2	3
7 Lesson exercises									11
6 Plan									5
5 Study/experiment								1	
4 Find out	▨				1		1	3	17
3 Find inferences				7	12		44	30	18
2 Draw				2	5		8	6	8
1 Calculate	■	63	59	59	82	133	137	91	96

Diagram 3



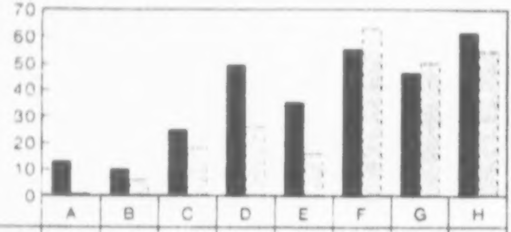
		A	B	C	D	E	F	G	H
8 Other				2	1		7	4	16
7 Lesson exercises									6
4 Find out	▨			2		2	8	5	5
3 Make inferences				3		1	13	13	2
2 Draw					3		2	1	1
1 Calculate	■	1	6	11	22	13	33	28	24

The results presented in the diagrams show large differences in the number of exercises. Newer books also have a far wider spectrum of the types of them. The three newest ones are significantly different from the others and one of them (H) has a new type of exercises, which are of experimental nature.

It was found, that the number of pages in each book does not give a reliable basis for any comparison due to large typographical differences in the books. However, it is only natural, that the number of pages dedicated to nuclear physics has drastically increased during the thirty year period under study. (Diagram 4)

Diagram 4

Nuclear Physics



	A	B	C	D	E	F	G	H
Number of pages	13	10	25	49	35	55	46	61
Number of exercises	1	6	18	26	16	63	50	54

The textbooks have followed the development in the aims and goals of teaching physics presented in the Finnish National Curriculum. In comparison with European teaching materials we may state that there have been some fresh ideas in the studied textbooks, but for instance some teaching materials available in United Kingdom and elsewhere have had quite a large variety of exercises already for a longer time. The differences may reflect also the nature of the maturity examination in each country.

References

Hanstein, V. 1985. Überprüfung einer Theorie der Textverarbeitung beim Lernen nach Physikschulbuchtexten unter besonderer Berücksichtigung von Zielvorgaben. Georg-August-Universität Göttingen

Joyce,B. and Weil,M. 1987. Models of Teaching. Prentice/Hall International Inc.

The Curriculum for the Finnish Secondary School. Physics and Chemistry. 1981. Helsinki. Kouluhallitus. Valtion painatuskeskus.

Merzyn, G. 1987. The language of school science. European Journal of Science Education 9, 483-489.

Strube, P. 1989. A content analysis of arguments and explanations presented to students in physical science textbooks: a model and an example. International Journal of Science Education vol.11. no.2, 195-202.

THE MICROCOMPUTER IN THE LABORATORY: CONTRIBUTIONS TO CONCEPTUAL DEVELOPMENT

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I. INTRODUCTION

Modern learning theory has shown that each student constructs his or her own personal world view. A critical factor in this process is the quality of each individual's interaction with physical systems and the personal effort expended to create explanations and understandings of a variety of physics concepts. The microcomputer, with appropriate transducers, can provide access to information about the real world and transform it into a form immediately useful for the student's own conceptual development. Many of the intermediate stages of data processing that often separated the observations from their potential contributions to concept development can now be bypassed. Demonstrations of concept rich microcomputer based laboratory activities will serve as the focal point for discussion of conceptual development.

A. Personal Involvement in MBL

1. Workshop

I began my work in MBL by collaborating with colleagues to develop a workshop to introduce physics teachers to the role that the microcomputer could play in the physics laboratory. We worked through the Apple game paddle port which provided the analog to digital conversion as well as digital input and output capabilities. This workshop was offered through the American Association of Physics Teachers and has been taken by over 15,000 physics teachers world wide.

2. NSF Grant

A colleague and I also have a National Science Foundation grant to prepare middle school teachers to have their students use microcomputer based laboratory (MBL) work to develop the students' concepts of heat and temperature, as well as their science process and graphing skills. We have worked with four school districts and 64 teachers, who in turn work with 5000 students. We have more MBL activities helping middle school students develop physics concepts than we have in our introductory laboratories at the University of Maryland in our introductory physics program.

B. Experimental Observations

Rather than begin with a review of the research being done in MBL I have chosen to illustrate the characteristics of and role to be played by MBL in the introductory physics course.

Today we will be using microcomputers as though we were introductory students looking at particular concepts in physics. We shall try to be self observant as to what role the MBL might play in student's physics conceptual development. We will look at the general context for MBL in the classroom and laboratory of the introductory physics course. Our work today will be in a demonstration mode, whereas our preference would always be to use it in a laboratory mode with no more than two students, the computer, and the associated laboratory equipment as our basic lab station.

II. BASIC SOURCES OF INFORMATION

In this presentation I will be referring to the work of two individuals. Ron Thornton of the Center for Science and Mathematics Teaching of Tufts University, and Arnold Arons, Professor Emeritus of the University of Washington.

A. Thornton MBL characteristics

Lets look at the MBL characteristics as defined by Ron Thornton[1] to remind us of the things to pay attention to as we carry out our experiments.

> **MBL provides an opportunity for students to do real science in their introductory encounters with physics principles and concepts.**

- **Students focus on the physical world**
- **Immediate feedback is available**
- **Collaboration is encouraged**
- **Powerful tools reduce drudgery**
- **Students understand the specific and familiar before moving on to the more general and abstract**

We will carry out a series of experiments and use the results to drive our discussion of conceptual development, and the role of MBL in this development.

B. Teaching/learning procedures

We will also utilize Arnold Arons' work as we carry out our experiments and pursue our discussions of the experimental results and observations. Arnold Arons provides a great many general guidelines in his new book **A Guide To Introductory Physics Teaching**[2]. We shall closely follow a subset of these suggestions in analyzing the physics to be rendered visible in our experiment and the way in which students should be interacting with the information provided by the experimental results.

1. Preconceptions:

Arons also describes the conceptions that students possess prior to their formal work in physics as pre-conceptions. Some are correct and some not. Our task as teachers is to find effective means of bringing about a change in the inappropriate student conceptions.

2. Arons' suggestions

Arons suggests that in order for students to assimilate abstract concepts of physics they must:

- **Utilize operational definitions[3]**

  Defining a term by reference to shared experience.

  Describing in simple words of prior definition, the actions through which one goes to develop the numerical value being referred to in the name of a technical concept.

- **Engage their own minds in active use of the concepts in concrete situations. The concepts must be explicitly connected with immediate, visible, or kinesthetic experience.[4]**

We as teachers must:

- **Learn to ask questions that lead the students to fully articulate the interpretations and explanations in their own words.[5]**
- **Demand students own words and stories in explanation of their observations prior to using the terms that science has chosen for these same observations and concepts.**
- **Ask the students to use concepts in a more extended manner, and in new contexts.**

Arons also emphasizes the need to:

- **Recognize graphical representation as an added perspective to modes of reasoning. Demand that students provide interpretations in their own words and in a fairly complete manner.**

III. EXPERIMENT {Cloud in a Jug}[6]

Lets turn to a series of short experiments which I suspect few of you have seen. This experiment has been designed in honor of Frank Oppenheimer who was the director and inspiration for the Exploratorium in San Francisco. When he and I toured the Exploratorium I immediately recognized the role that a computer could play in instrumenting one of the experiments he showed me, and after he died I decided to work this out in his honor. There is still one element not finished that I will comment on later.

We will carry out the experiments in stages, discussing the results at each stage. Our great disadvantage today is that when working as a single group we will accept a single individual's explanation assuming it is representative of each person when we know it is not. Furthermore, these explanations are shared with the whole group, not simply within smaller laboratory groups working at their own laboratory stations. The variety of explanations that would exist in smaller groups will not emerge today.

A. Experiment: Part 1

I have placed a temperature measuring probe in the center of this glass container. We are going to place a stopper on the chamber and use this bicycle pump to pump air into the chamber. We will be able to produce a temperature vs time graph of the experiment as it proceeds. Your task is to predict what will occur as the air is pumped into the chamber -- (Air will be pumped in and the pressure allowed to buildup to the point that the cork will spontaneously pop out releasing the pressure abruptly). The results of our first experiment are shown in the first graph labeled Helsinki 1, (Fig. 1.)

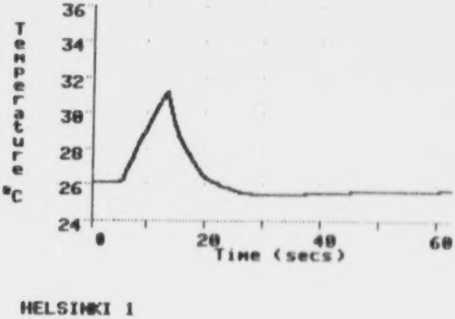

Fig. 1. Temperature vs. Time graph as air is pumped in and then allowed to abruptly escape from the chamber

Before discussing the results of this first experiment we will run the experiment a second time with a modest variation in the procedure -- (No air will be allowed to escape). The results of the second experiment are superimposed on the first and shown in the graph labeled Helsinki 2, (Fig. 2.)

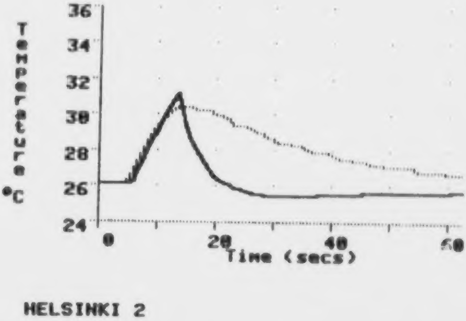

Fig 2. Temperature vs. Time graphs of the initial experiment plus the second (dotted line) in which air was pumped in but not allowed to escape.

B. Discussion Part 1

We will try to limit the initial discussion to information that is visible in the graph and things that that were observable as the experiment progressed. Temperature rise, fall, and the character of the temperature changes are clearly visible, and we must recognize that pressure can be discussed especially if the individual making the response was the one the doing the pumping or someone who clearly heard the pumping and the rush of air out of the chamber as the stopper "popped".

The proper information is clearly visible to allow the student to operationally define and recognize differences in the kinds of temperature changes that occurred. This is true, as shown in the relatively abrupt temperature changes on both sides of the early part of the original graph (Fig.1), in contrast to the normal warming which occurred as the remaining air returned to room temperature in the latter part of the graph. It is also true in the second part of the experiment. Fig. 2 shows an early, rapid temperature change, followed by normal cooling as the heated air returns to room temperature. As physicists we immediately recognize temperature changes that have occurred due to work being done on and by the system as well as heat energy entering or leaving the system under normal conditions. The students will not share this insight at this point, calling all three regions where temperatures changes occurred as heating or cooling, and all of our skills as a teacher will be needed to help them identify and personally describe the important temperature information rendered visible in the graph, and eventually relate this to the thermodynamic processes that must include work, not simply heat transfer.

The graph clearly illustrates the "adiabatic" processes of temperature change associated with work being done on and by the air in this experiment. The students however, do not come armed with a ready definition of adiabatic and should be allowed to describe the difference in the three regions of temperature change and arrive at an explanation that can be the basis for their eventual use of the term "adiabatic."

C. Experiment Part 2

We will now run a third experiment complimenting the first two by simply releasing the pressure after the air in the chamber has returned to room temperature. The results are shown in Fig. 3.

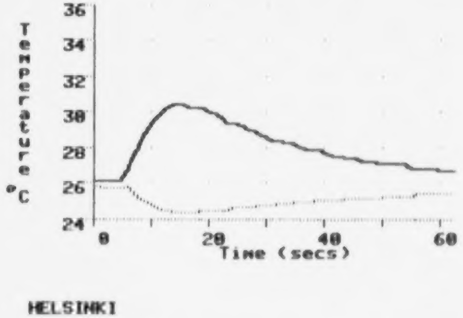

Fig. 3. Dotted line (lower) shows temperature changes when the pressure is released after gas returns to room temperature.

D. Discussion Part 2

This final "cooling" below room temperature (when the second pressure release occurs) followed again by normal warming, is clearly a third example of adiabatic cooling associated with the air doing work on its surroundings followed by normal heating of the remaining air by heat energy exchange. This qualifies as using the adiabatic and normal cooling concepts in an extended manner as suggested by Arons.

A major problem is that it is difficult to expect students to understand that work was done on or by the gas and that this work accounts for the adiabatic portion of the heating or cooling curve. The fact that we can not yet monitor and graph the pressure of the gas at the same time as the temperature is a shortcoming that will be solved as the unfinished portion of this work. This should help students' conception of work and the role it played in bringing about temperature changes.

A second element for the students is that this is not an enclosed gas subject to the PV=nRT rules that students encounter in physics and chemistry.

This is clearly an experiment that can be related to the students' meteorology knowledge of cloud formation and to other processes in chemistry, phyiscs and biology.

IV. GRAPH CHARACTERISTICS

Arnold Arons also recognizes "graphical representations as added perspectives to modes of reasoning."[7] It is obviously the key element in the transposition of the data gathered in these experiments into a form that potentially gives each student access to various physical parameters and therefore the inner workings of this experiment. The microcomputer based laboratory has an ability to provide students with a rich array of graphical presentations leading to qualitative understanding of many physics concepts.

V. CORRECT VIEW DEVELOPMENT

Lets now look at Arnold Arons' statements on Pre-Conceptions and Correct View Development.

> **PRE-CONCEPTIONS AND "CORRECT VIEW" DEVELOPMENT**
>
> **Learners must be confronted with direct experience, and with contradictions and inconsistencies, in such ways as to induce them to articulate lines of argument and reasoning in their own words and to lead them to abandon the deep-seated, plausible, intuitive preconceptions that impede development of the contra-intuitive but "correct" view.**
>
> **Most learners require several such encounters, distributed over time in increasingly rich context, and one must not expect to "rectify their disabilities" in one remedial session.[8]**
>
> **Clear and vivid presentations, together with conventional quantitative problems, must be supplemented with questions and problems that engage the minds of learners in qualitative, phenomenological thinking.[8]**

VI. SECOND EXPERIMENT (Cu Cylinder)

I would like to describe a second experiment that we would carry out if time was unlimited, one that fully supports "Correct View Development." It is an experiment that can lead students to invent a concept to successfully account for experimental results and perhaps "abandon deep-seated, plausible, and intuitive concepts".[9]

A. Experiment

The experiment consists of placing a hot 250g copper cylinder in a beaker containing 250g of room temperature water. The student's task is to estimate the time that should chosen so that we will obtain a record of the full range of temperatures of the two parts of our system, and make a prediction of the final temperature of the cylinder and water at the end of the experiment.

The temperature history of both the cylinder and the water will be presented on a temperature vs time graph. The result is shown in Fig. 4.

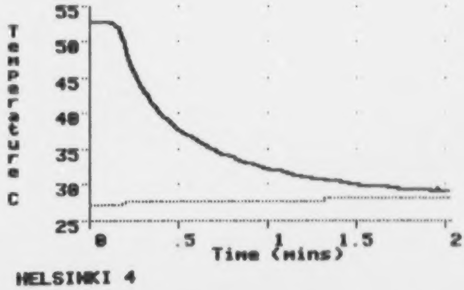

Fig 4. Temperature vs Time graph of a copper cylinder and equal mass of water as the hot cylinder is immersed in the cold water.

B. Discussion

Was the final temperature the value which you predicted? In the USA the most common prediction of both students and teachers is a temperature half way between the initial temperature of the Cu cylinder and the initial temperature of the water.

Almost as soon as the experiment begins, the great change in the temperature of the cylinder in contrast to very small change in the temperature of the water offers immediate visual feedback that the intermediate temperature predicted by most will not be honored by Mother Nature.

As the students realize the inaccuracy of their predictions, many will begin to offer reasons for the observed difference in the temperature changes of the copper and the water. Some will immediately suggest that the cylinder gave up more heat energy than the water absorbed. This provides evidence that students and teachers are making their prediction based on only temperature changes, a clear indication of a pre-conception in need of changing. Classmates, however, will quickly point out that the cylinder is immersed in the water, so that all the heat energy transferred from the cylinder is acquired by the water.

If the class or laboratory group can agree that the heat energy exchanged was indeed he same, and that the masses were the same, then the only thing remaining to account for the extreme difference in the temperature changes of the water and the copper, is a fundamental difference in the behavior of copper and of water. This leads to the need or opportunity to invent the concept of specific heat. If the students have followed the behavior of this system and can fully describe its behavior in their own words, they will possess a "shared experience" that can serve as the basis for an operational definition of specific heat prior to the formal introduction of that term.

VI. RESEARCH IDEA.

I would like to share one new conceptual development approach that would take full advantage of the copper cylinder, the ability to monitor its temperature, and the ability of the computer to transform this information into a form useful to the student.

Because we know the cylinder's mass, its specific heat, and can monitor the temperature changes it undergoes, we could easily provide a digital readout of the energy gained or lost by the cylinder during an experiment and express the information in calories or joules. We could also provide a graph as well, although there are some fundamental conceptual difficulties related to the kind of graph that physics would allow us to provide.

If we wish students to develop good energy concepts we should offer instruments that provide first hand energy information about an experiment. Cylinder use with energy readout could help change the pre-conceptions that are evident in students when they ignore mass as a critical element in accounting for energy gains or losses as objects heat or cool, or when they do not recognize that mass on the other hand plays no role in determining the direction of energy exchange between two systems at different temperatures. Students could be asked to design experiments for adding or removing heat energy from the cylinder, and carry out equivalent experiments with cylinders of various mass and composition They would soon realize that the only factor in determining whether the cylinder would gain or loose heat energy would be the relative temperature of the cylinder and its surroundings, and that mass and composition are significant factors under other circumstances.

Conceptually there are some difficulties. One should not imply that once added, heat energy is stored in the cylinder. One should only specify that the temperature change was due to heat energy entering or leaving the cylinder. Graphs of energy changes also present difficulties. One would not want to subject a cylinder to to a variety of temperatures and imply that a graphical account of energy changes implied putting energy in and later removing it. Much work remains in this area.

Of course liquids provide another challenge. Thermal gradients may develop within a liquid so that the temperature at a given location is not indicative of energy gained or lost by the mass.

I would still maintain, in a conceptual change context, that students could certainly learn to use the cylinder to supply heat, or absorb heat and gain a good first hand sense of the calorie or the Joule as a direct indication of energy change - not be simply left to infer this from temperature changes, knowledge of specific heats, and the mass of the object involved, which is our common approach today.

VII. ADDITIONAL REFERENCES

Arnold Arons has provided such a rich and up-to-date array of references on alternate conceptions that I will not try to duplicate that but encourage each person to refer to Arnold's book.[2]

Lillian McDermott's article in a recent *American Journal of Physics*[7] describes research on computer-based instruction that deals with non-MBL computer activities for students. I do not presume to discuss this aspect at all, but highly recommend the article.

Ron Thornton provides a comprehensive accounting for the conceptual progress of physics students who have an opportunity to use a motion probe. This will be published in the *American Journal of Physics* as well.[1] He will also publish a broader description of MBL improvements in student physics conceptual understandings in *La Fisica nella Scuola*.[8]

The broadest array of references to computers and their role in physics teaching is found in the *Proceedings of the Conference On Computers in Physics Instruction*, a conference held in 1988.[9]

The software used to run these experiments was an early version of the HRM Heat and Temperature program. This version runs with thermistors not the later versions which require the Red Box.[10]

There are now many sources of software and hardware enabling the microcomputer to serve in student conceptual development in the laboratory.[11]

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[1] Ronald K. Thornton and David R. Sokoloff, "Learning motion concepts using real-time microcomputer-based laboratory tools", *Am. J. Phys.* To be published, August 1990.

[2] Arnold B. Arons, *A Guide to Introductory Physics Teaching*, John Wiley & Sons, New York, 1990. ISBN 0-471-51341-5

[3] Arons, 15

[4] Arons, 38

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[5] Arons, 4

[6] John W. Layman, "Laboratory interfacing of microcomputers", AIP Conference Proceedings **173**, 289-291, Cooperative Networks in Physics Education, Oaxtepec, Mexico 1987, American Institute of Physics, New York, 1988

[7] Lillian C. McDermott, "Research and computer-based instruction: Opportunity for interaction", *Am. J. Phys.* **58**, 452-462 (1990)

[8] Ronald K. Thomton, "Using the microcomputer-based laboratory to improve student conceptual understanding in physics", *La Fisica nella Scuola*, publication date unknown. or can be found in *Microcomputer in Physics Education*, the proceedings of an international conference held at Cukurova University, Adana, Turkey in Sept. 1989.

[9] Edward F. Redish and John S. Risley, *The Conference on Computers in Physics Instruction Proceedings*, (Addison-Wesley Publishing Co., Reading, MA., 1990)

[10] The HRM Heat and Temperature program is now handled by Queue, Inc., 562 Boston Avenue, Bridgeport, CT 06610

[11] Vernier Software, 2920 S. W. 89th St., Portland, OR 97225. Provides the greatest variety in inexpensive laboratory interfacing equipment, software, and technical ideas and kits and parts for the do-it-yourselfers.

New Computer Demonstrations in Physics Teaching.

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In resent years computer techniques have been widely used in teaching physics. There appeared a great deal of publications in periodicals concerning this problem. Computers are used for visual illustration of physical concepts and phenomena, simulation of the physical processes, solution of physical problems etc. Computers are also applied in physical laboratories as students carry out experiments, during seminars, individual studies and lectures. All those who delivered lectures on physics are quite aware that traditional lectures at the blackboard with a piece of chalk in your hands are no longer popular with the students . Looking for new style of lecturing is indispensable and important. In this respect computer demonstrations with a neatly arranged color graphics, with the possibility to change parameters and conditions of simulation of the physical process suggest unlimited opportunities which unfortunately are not used to the full (at least in the USSR) mainly because of the lack of high quality computers and suitable software.

As mentioned above, a good deal of programs on the mathematical simulation of the physical phenomena have been developed up to the present. But no high quality course of general physics (designed for students-physicists) using a whole spectrum of physical computer models has so far been created.

Many of the existing computer courses are mostly aimed at teaching programming whereas physics as such is considered as a sort of a "training ground" for programmers. We adhere to another pedagogical concept.

In 1989 the MIPT department of physics together with the student's computer laboratory started developing the packet of animated computer demonstrations in teaching physics. The ultimate goal of this co-work is to develop integral courses for all parts of physic with application of computer simulation and demonstrations. These courses must certainly not replace traditional methods of teaching, but they might constitute a parallel, additional branch of it.

Gradually it became clear that mathematical programming must remain "out of sight" in the programs simulating physical phenomena and designed to teach physics. Programming must not divert student's attention from the essential physical problem.

The development of such courses proved to be painstaking and complex involving both physicists and programmers of high qualification. This work is carried out by students with the help of physicists guiding them. Thus the process of developing and creating such programs simulating physical phenomena, is in itself a kind of teaching method, which the students are exclusively interested in.

Personal Computer of IBM PC/AT type are used, C is used as a programming language which guarantees high speed and compatibility with the other software.
It is expedient for the physical "scenario" and the program arrangement to be maximally flexible so that in a brief variant the program might serve as a lecture demonstration, then in a broadened variant it might be an addition to seminar and laboratory studies, and finally in a complete variant the program might be effectively used during individual studies. The last variant assumes additional methodical supplies and wide possibilities of student-program interaction.

Some examples of computer simulations in physics are presented in this paper. It is but a minor part of worked out programs in question. At present there are approximately 60 programs of different levels of completeness. The most advanced are sections of "Molecular Physics" and "Wave Optics".

To present a proper perspective of our work we consider here examples of the programs some of which are illustrated by display screen pictures.

1. Adiabatic gas process. A two-dimensional ideal gas model is used (gas of hard discs). Collisions between molecules and with the walls are calculated in accordance with the laws of mechanics (elastic collision), computer memory retaining coordinates and velocities of all the particles. Volume may contain up to 50 particles. Theoretical adiabatic curves are compared to the calculated curves. Fragment of described program is presented on Fig 1. Isothermal process could be illustrated with the help of the same program.

2. Boltzmann distribution in the potential field. The same hard disks model is used. Parameters (gas temperature and acceleration of free fall) can be changed. Theoretical curve is compared to the calculated histogram. The program assumes the storage of information with a subsequent averaging. Corresponding display screen is shown on Fig 2.

3. Maxwellian distribution for the mixture of light and hard molecules. At the initial moment all the molecules have the same speed, which can be changed. The program allows to observe "maxwellization" - setting up the equilibrium velocity distributions different for light and hard fractions /Fig 3/.

4. Brownian motion. The program provides for a multiple repetition of the experiment and subsequent averaging of the results. Diffusion law is demonstrated. Interaction of molecules with a Brownian particle is calculated in accordance with the elastic collision laws /Fig 4/.

5. Fluctuations of a number of particles in a chosen volume. Probability distribution of

the presence of a given number of particles in the chosen volume is calculated. Histogram averaging is provided for. This program enables to demonstrate the inverse proportionality of the distribution width to the square root of the number of particles. The number of particles in the problem concerned reaches up to 200.

6. Thermal motion of a piston on a spring. This oscillation system model which is in equilibrium with the gas enables to observe thermal fluctuations of the gas volume under the piston. Gas temperature change is assumed. Piston's motion on the screen may be observed in real time and on a large scale. The program calculates interaction of molecules with vessel walls and the piston according to the laws of mechanics. The program provides for the averaging of the results. The average histogram is approximated by a Gaussian curve.

7. Gas mixture entropy. The program illustrates the entropy increase in gas mixture after removal of a separating wall. The program realized the entropy calculations according to statistic formulae and comparison with macroscopic results.

8. Heat conductivity. The program illustrates the process of energy transfer from the hot wall to the cold one. The same model of two dimensional gas is used.

9. Mechanical problem - gyroscope precession and nutations. The trajectory of vector end of angular momentum when acted upon by different initial pushes is shown.

10. Fourier-analysis and synthesis of periodic signal. The program brings about the decomposition of a Fourier spectrum of a wide range of periodic functions, demonstrates separate harmonics and finally realizes Fourie synthesis of signal out of any given number of harmonics.

11. Fourier optics. The program enables to illustrate Fresnel and Fraunhofer diffraction laws, the self-reproduction phenomenon etc. It also enables to construct more complex optical systems consisting of the combination of grids, lenses and aperture diaphragms. The algorithm of a Fast Fourier Transform is used /Fig 5/.

12. Diffraction grid as a spectral device. The program illustrates the concepts of angular dispersion, dispersion region and the resolution power of optical spectral instruments. Wide possibilities for choice of parameters of the grid and incident light characteristics are provided for.

13. Light polarization. The program illustrates elliptical polarization as a result of addition of the two perpendicular oscillations, their amplitudes relation and their phase shift can be chosen arbitrarily. We may see on the display screen the movement of field vectors of elliptically polarized wave /Fig 6/.

Two-dimentional model of ideal gas

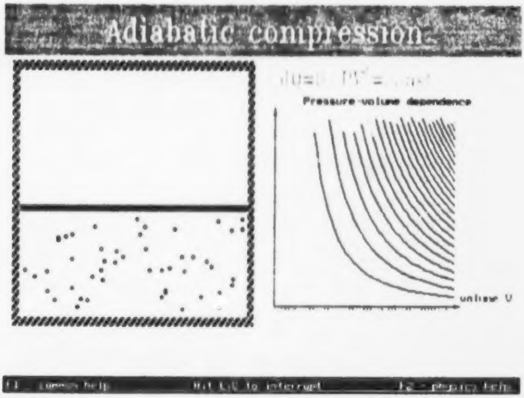

Adiabatic compression
Pressure-volume dependence
volume V
F1 - common help
Hit ESC to interrupt
F2 - physics help

Fig.1

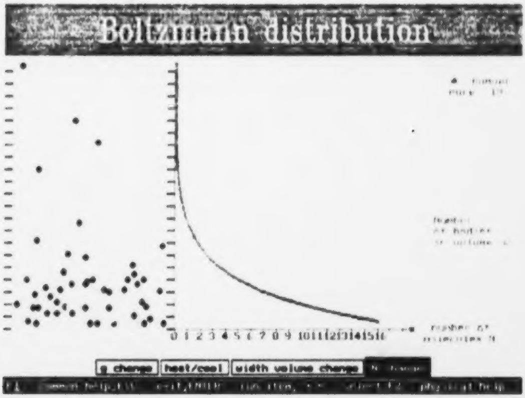

Boltzmann distribution
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
number of molecules N
g change
heat/cool
width volume change
N change

Fig.2

Two–dimentional model of ideal gas

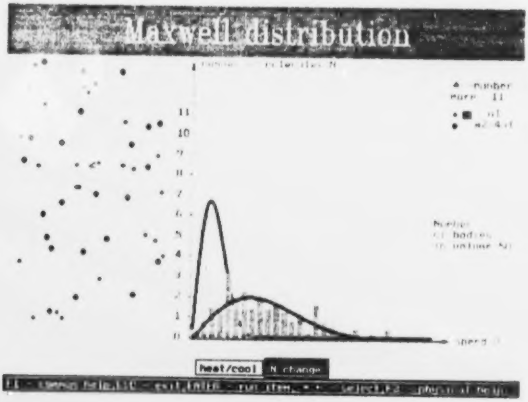
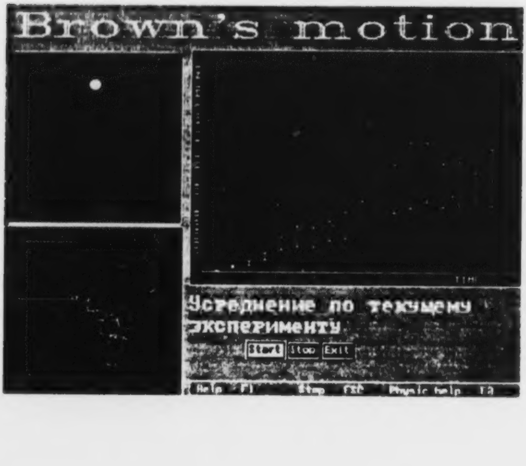

Maxwell distribution
11
10
9
8
7
6
5
4
3
2
1
0
speed
number
bodies
heat/cool
N change

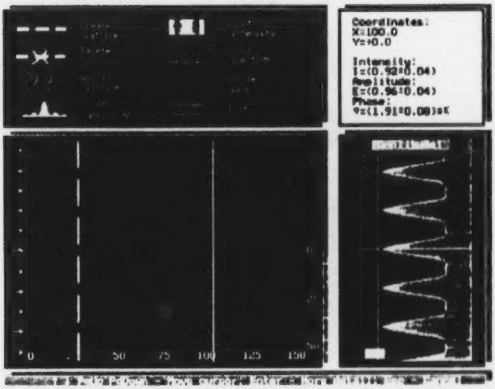
Fig.3


Brown's motion
TIME
Start
Stop
Exit
Help F1
Stop ESC
Physic help F3

Усреднение по текущему эксперименту

Fig.4

Fourier Optics

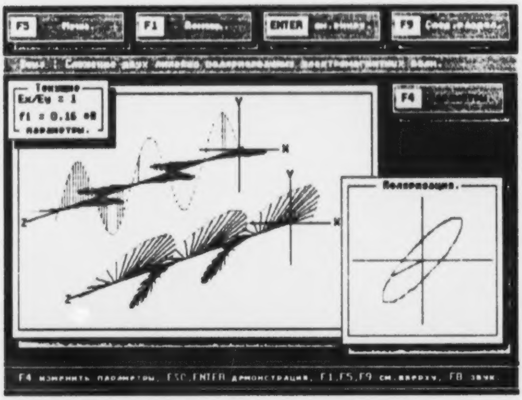

0
50
75
100
125
150

Coordinates:
X=100.0
Y=+0.0

Intensity:
I=(0.92±0.04)
Amplitude:
E=(0.96±0.04)
Phase:
φ=(1.91±0.08)π

Fig.5

Light polarization


F5 Меню.
F1 Помощь.
ENTER см.внизу.
F9 Содержание.
F4
Y
X
Z
Y
X
Z
Поляризация.

Демо 1 : Сложение двух линейно поляризованных электромагнитных волн.

Текущие
Ex/Ey = 1
f1 = 0.16 π
параметры.

F4 изменить параметры, ESC,ENTER демонстрация, F1,F5,F9 см.вверху, F8 звук.

Fig.6

Of course, we don't take it for granted that many ideas of computer programs in question are by no means new. We tried to use the high computer speed to the maximum and perform physical scenarios considering computer graphic possibilities for visual illustration of physical phenomena and processes. In this respect we seem to achieve some progress. We should like to emphasize once again that these computer animated demonstrations enjoy great popularity among students and thus must be undoubtedly used in teaching physics.

The course "Physics on the computer" as we have called it, is not representing on-line tutorial programs. In our opinion tutorial programs have low effectiveness in physics teaching because physics is not only educational discipline but a world outlook too. Nothing could substitute the creative interaction between teacher and student in teaching physics.

ACKNOWLEDGMENT

The author would like to thank Dr. N. Soboleva and Dr. A. Iljin for helpful discussions and members of student's computer laboratory, especially A. Pshenitcin, K. Buharov, A. Shurna.

SATELLITES IN EDUCATION AND TRAINING IN EUROPE AND NORTH AMERICA

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The use of satellites has been broadened quickly also to the educational sector. Satellite training is already used to a large extent in the United States and in Canada; Europe has been taking its first steps. In the USA there are several satellite programs already working - for example National Technological University (NTU) and National University Teleconference Network (NUTN). It should also be emphasized that the different large companies in the United States have quickly adopted the idea of Business Television which has as an integral part also training in companies. Thus at least some part of the training programs of the companies will be delivered by satellites in the future.

However, it should also be stressed that in many countries with unusual geographic conditions (like Canada with its large area, India, Australia, Indonesia, the South Pacific with many islands and West Indies) satellite training has been of key importance for developing the educational infrastructure of the country.

It has been often forecasted that modern educational technologies will play an essential part in the future education and training especially in the developing countries. This is due mainly to the lack of resources in the conventional education and training. However, it must also be recognized all the time that television as such is a complicated educational tool due its cultural heritage. The television set is often seen in the context of entertainment and leisure time and the wide use of television for educational purposes needs a very good educational design of the programs delivered.

Usually the use of satellites in education and training is understood to be only transmittance of video and audio signals. However, new technologies applied in the educational satellites allow also simultaneous transfer of data. An interesting option for the future are such low-cost satellites which are working mainly as tools for transmitting electronic mail messages.

The essence of satellite training is that it can be a quick vehicle for education and training in covering large geographic areas. In the delivering of training the satellite makes possible good access to remote areas. In many cases satellite training despite its high costs can be relatively inexpensive per user. However, one should realize that the cost of satellite transmission either requires certain "critical masses" (by economic terms) or the absolute need for real-time transmission.

In the cost structure of different programs the transmission cost is not the major cost. The planning costs, the editing costs, the administration costs and the different overheads are usually at least of the same size as the transmission cost as such. This fact should be realized by the persons or institutions which are planning to use satellite transmissions in their education or training programs. The cheap access to satellites will give an advantage but as a rule-of-thumb the transmission cost as such is usually hardly more than a quarter of the total costs of the program.

Satellite education and training has many benefits which can not be denied. Some of them can be listed as follows:

- satellite education and training by its real-time character offers possibilities for quick transfer of knowledge; the lead-time compared to research reports, books or scientific journals is very short; this fact is of increasing importance especially in fields like information technology where the life-cycles of products are shortening fast
- by satellite education and training it is possible to reach experts and professionals which by conventional means would be impossible to reach and use them for educational purposes nation-wide or world-wide
- satellite education and training can in an ever more international world be used also transnationally - like the European programs EuroPACE and Olympus
- satellite education and training offers - like distance education and training in general - possibilities for persons to attend a high-quality education and training regardless of their location and timetable.

The technology used in satellite education and training is relatively reliable today - the real problems in the use of satellite education and training are partly the costs (both in possible facilities, studios, uplinks etc. as well as in production of the programs) and partly in organizing the interaction between teachers and students as well as between different individual students in proper ways.

Usually satellite education and training is a one-way audio - one-way video event. However, the interaction is to some extent possible by satellite technology (two-way video - two-way audio) although it is very expensive.

One should rather focus on the use of other educational technologies in supporting the satellite education and training. Thus the satellites should be understood in the context of multimedia education and training. In this approach the satellite transmissions are backed by other educational activities (e.g. audio conferencing or computer conferencing as interactive media; prints, video cassettes, audio cassettes and other audiovisual media etc.). The educational and training goals set by the trainers are often impossible to reach only by one-way satellite transmission and a real learning context always requires the interaction.

Finally one should stress that the future of satellite education and training looks bright. The costs of the use of satellite time is going to decrease due to the new developments (like low-cost satellites). On the other hand the interactive media to support the satellite training have been developing very fast during the last years and their cost-benefit ratio has been improving steadily (e.g. computer conferencing, video conferencing, audio conferencing). It is my firm belief that satellites will offer in the near future an even more powerful tool especially in international education and training and that they can be used also cost-effectively for smaller audiences than today.

THE MINERVA PROJECT AND THE TEACHING OF PHYSICS

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The MINERVA Project, is a Portuguese Project initiated in 1985 which main purposes are the introduction of the new information technologies in Education.The Project looks for a valorization of the Educative System in all directions.

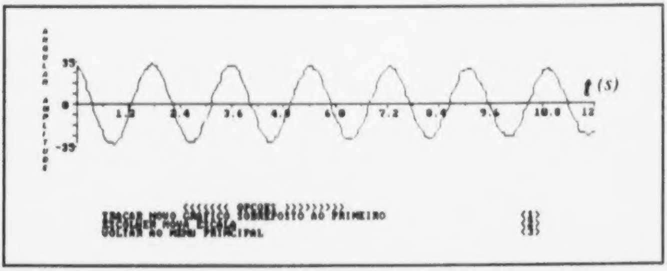
In the field of Physics Education, the MINERVA Project works in two areas: making simulation software and using the computer as an aid in the laboratory. Our activity in the University of Évora is an attempt of applying computer in Physics lab. In spite of the fundamental role of data acquisition, we pretend making easier some Physics concepts by means of their exploitation as well as its differentiation (ex. heat and temperature). The use of computer in the laboratory pretends to be an aid in "the building of bridges for new conceptions" (R.Driver, 1988).

Our activities turn around graphics constructions while an event takes place, allowing us "to feel" how the graphic might be the report of a"story". These graphics emphasize nature "imperfection" (riches) which is allways forgotten in school manuals. On the other hand, we'll use these graphics to stimulate student's criticizing mind facing them with absurd situations.

1- **Gravitic pendulum movement** - Fig.1

We pretend here: 1) that students realize about the difference between trajectory and time-position graphic, moving the pendulum "by hand". We might introduce also here, the amplitude and period concepts; 2) observe pendulum damping; 3) "investigate" the relationship between the pendulum period with the mass and length in a qualitative way.

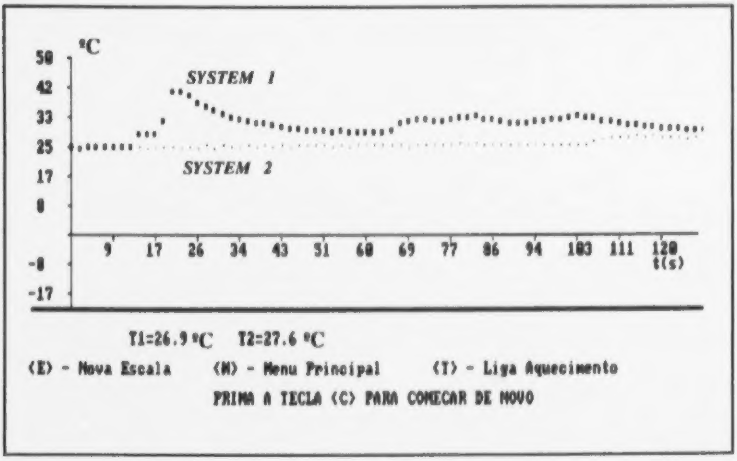
Fig. 1



2- Differentiation between heat and temperature concepts - Fig.2

With the activities we propose we can attain the differentiation of the concepts of heat and temperature but we can't conceptualise them. So we think this activity should be followed by the use of some heat dynamic modelisation software.

Fig.2



T1=26.9 °C T2=27.6 °C

(E) - Nova Escala (M) - Menu Principal (T) - Liga Aquecimento

PRIMA A TECLA (C) PARA COMECAR DE NOVO

DRIVER,R (1988). Theory into pratice II: a constructivist approach to curriculum development [in FENSHAN, P. (ed). Development and Dilemmas in Science Education], London: The Falmer Press.

Educational Technology Center, Harvard Graduate School of Education; A Position Paper on the Role of Technology in Science, Mathematics and Computing.Educations, 1988.

EMPIRICA - A PROGRAM FOR DATA ACQUISTION AND ANALYSIS IN SCIENCE TEACHING AND ITS PEDAGOGICAL APPLICATIONS

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Summary

We have developed a versatile microcomputer based system including new software and hardware for data acquisition and analysis in science teaching (Lavonen & al. 1989). The hardware is designed to be connected to IBM PC/AT/PS computers. The software use a Windows type of interface and allow several methods of data analysis and graphical visualization. The data can also be transferred under other programs for further analysis and reporting.

Also a pedagogical research and development program has been initiated to produce teachers' materials as well as different practical approaches to the problems of teaching-learning situation in schools. The first qualitative results of the evaluation of our approach support the claims of the pedagogical versatility of our approach. Our system is already in use in several Finnish schools.

Background

During the last few years many investigations have been made into how pupils of different age groups predict and explain natural phenomena (e.g. Driver 1983). The main result of these investigations is that pupils' conceptions of natural phenomena are markedly different from the concepts of the teaching program. Also abstract scientific concepts have proved difficult for many pupils to understand. Perhaps they know the formulas, equations or mathematical methods but they don't understand what natural laws really mean.

One method to improve pupils' understanding of physical concepts is to increase investigations of real phenomena. Computer is an excellent assistant when we want to increase the number of experiments during the physics lessons. It helps for example in the data collection, in the differentiation and integration of data, in the curve fitting of the data and in the numerical or graphical display of data.

Pedagogical ideas

When we are using computer in teaching, it isn't a solution to better education. We must understand that computer is only a tool, when we are interacting with nature. In addition we must remember to communicate with our pupils. Computer assisted learning interaction contains three dimensions: human interaction, interaction with nature and logic of thinking process. When we are teaching, there is one component from every dimension in the learning interaction (Meisalo & Tella 1987).

When we are using computers in science teaching the learning can be described by "Extended Market Square" model (Fig. 1) (Meisalo 1987, 1989). Computers are used here mainly as tools when pupils are working towards goals.

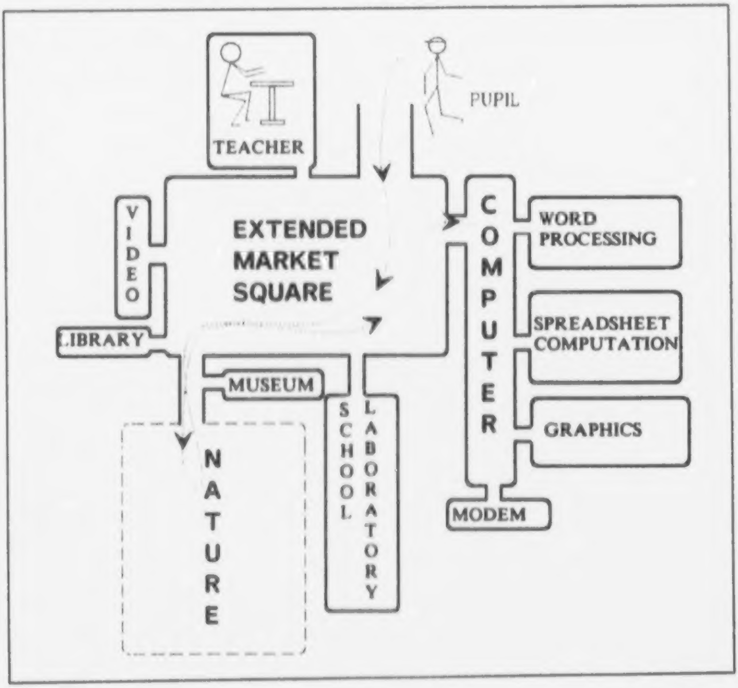
TEACHER
PUPIL
VIDEO
EXTENDED MARKET SQUARE
LIBRARY
MUSEUM
NATURE
SCHOOL
LABORATORY
COMPUTER
WORD PROCESSING
SPREADSHEET COMPUTATION
GRAPHICS
MODEM

Figure 1. "Extended Market Square" model.

Another important idea behind our software is the experimental approach in science teaching which is a natural way of teaching physics (example Kurki-Suonio & Kurki-Suonio 1987). The starting point in teaching is the observation of a phenomenon in nature. After the recognition of the phenomenon we get quantitative knowledge of the phenomenon by measurements. Natural laws can be defined by presenting invariances between entities. A group of laws forms a theory. The theory and the laws can be applied when we are analysing new phenomena (Fig. 2).

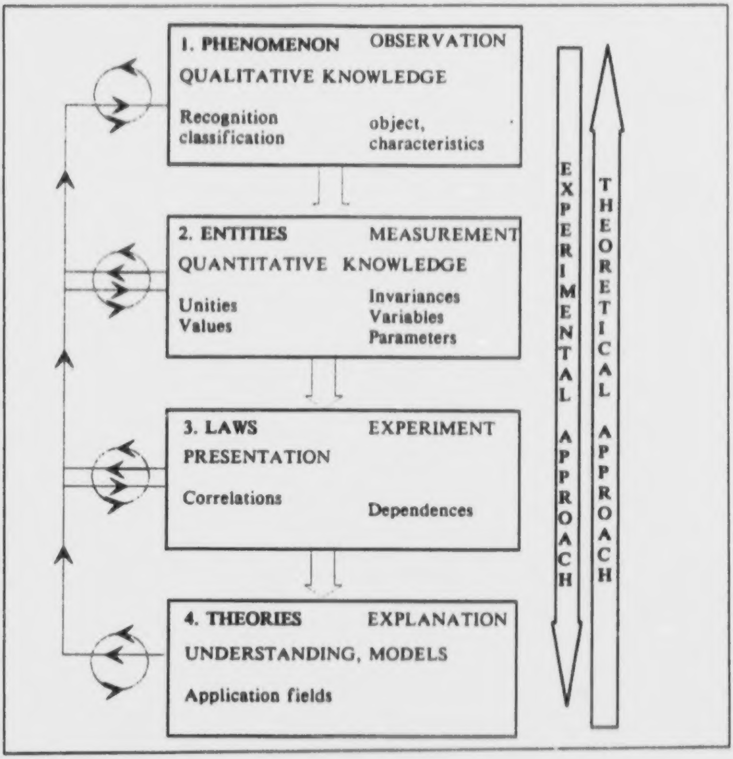
1. PHENOMENON
OBSERVATION
QUALITATIVE KNOWLEDGE
Recognition
classification
object,
characteristics
2. ENTITIES
MEASUREMENT
QUANTITATIVE KNOWLEDGE
Unities
Values
Invariances
Variables
Parameters
3. LAWS
EXPERIMENT
PRESENTATION
Correlations
Dependences
4. THEORIES
EXPLANATION
UNDERSTANDING, MODELS
Application fields
EXPERIMENTAL APPROACH
THEORETICAL APPROACH

Figure 2. Experimental approach in science teaching.

The software has been planned to help us to present the correlations between entities in many different ways. For example graphical display of data or curve fitting helps us to analyse the dependence between variables and formulate the natural law.

The Data Acquisition System and Software

In 1987 we began using the computer as a laboratory instrument in the physics courses and started to develop interfaces and software for Compis and IBM microcomputers (PC, AT, and PS/2). The interface is connected to the serial port of the computer (COM1 or COM2). The measurement unit and the sensors are connected to the interface. A system for photogate measurements is presented in figure 3 .

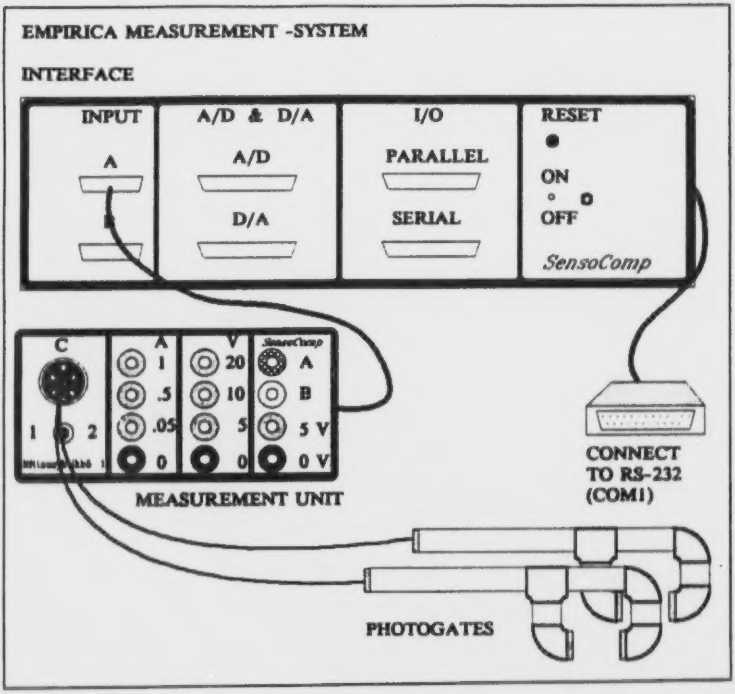
EMPIRICA MEASUREMENT -SYSTEM
INTERFACE
INPUT
A
B
A/D & D/A
A/D
D/A
I/O
PARALLEL
SERIAL
RESET
ON
OFF
SensoComp
C
A
V
SensoComp
1
.5
.05
0
20
10
5
0
A
B
5 V
0 V
1
2
MEASUREMENT UNIT
CONNECT
TO RS-232
(COM1)
PHOTOGATES

Figure 3. Interface, measurement unit, and photogates.

The software uses a Windows type of interface (Fig. 4). The software and the hardware allow us to measure time, velocity, acceleration, angular velocity, angular acceleration, and study the motion with photogates. Voltage, current and resistance are measured by V/f- or AD- converters. For other entities we have sensors for temperature, light, pH, conductivity, strain, magnetic field, and pressure.

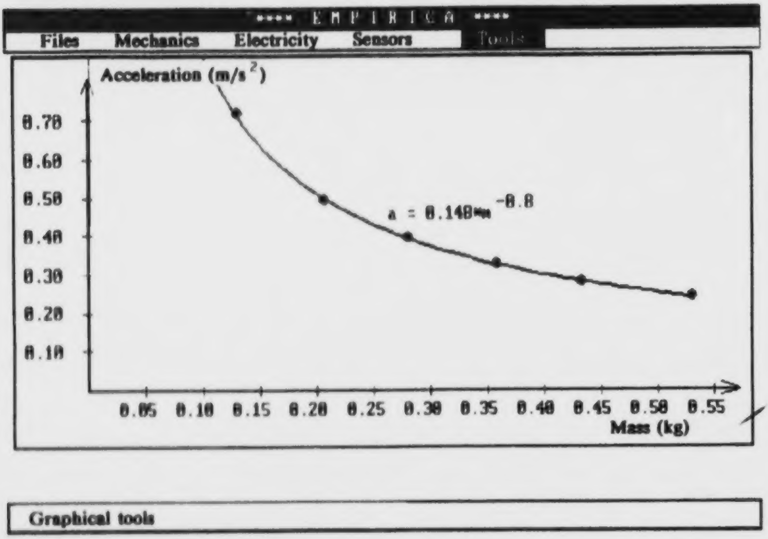
**** EMPIRICA ****
Files
Mechanics
Electricity
Sensors
Tools
Acceleration (m/s²)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
a = 0.140m^-0.8
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
Mass (kg)
Graphical tools

Figure 4. The screen of the computer.

The data can be presented numerically or graphically. There are also mathematical and graphical tools for example for the curve fitting of the data and for the graphical differentiation or integration of the data. The data can also be transferred under other programs for further analysis and reporting (Lavonen 1990).

References

Driver, R. 1983. The Pupils as Scientists?. England: Open University Press,Milton Keynes.

Kurki-Suonio, K. & Kurki-Suonio, R. 1987. Kokeellisen ja teoreettisen lähestymistavan tuntomerkit fysiikan opetuksessa (Experimental approach in science teaching, in Finnish). Helsinki: Report series in physics, University of Helsinki.

Lavonen, J.,Kåll, L, Simbierowichz, P and Knuuttila, M. 1989.Empirica - mittausjärjestelmä (Empirican measurement system, in Finnish). Vantaa: SensoComp Ky ja Printel Oy.

Lavonen, J. 1990. New software and hardware for data acquistion and analysis in science teaching and their pedagogical applications (in conference proceedings: EURIT 90, A European Conference on Technology and Education, April 23 - 27, 1990, Herning, Denmark). Edited. Eurit 90 Conference Secretariat, CPI, Danish Centre for Education and Information Technology, Copenhagen, Denmark.

Meisalo, V. 1987. L'informatique dand l'enseignement des matieres. Le point de vue didacticiel. Colloque franco-finlandais sur les technologies nouvelles en education. Les Actes. Paris 16 - 20 novembre 1987, 57 - 61.

Meisalo, V & Tella, S. 1987. Tietotekniikka opettajan maailmassa (Information technology in the world of teachers, foundations of didactics of informatics and the use of computers in teaching, in Finnish). Keuruu: Otava.

Meisalo, V. 1989. The Finiste Network and Pedagogical Research, in conference proceedings: Meisalo, V. & Kuitunen, H. ed. 1989. Innovations in the Science and Technology Education. Helsinki: National Board of General Education.

Wilson, J. & Redish, E. 1989. Using Computers in the Teaching of Physics. Physics Today, January 34 - 41.

THREE COMPUTER PROGRAMMES FOR JUNIOR HIGH SCHOOL

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Many schools have computers now, and we have to learn how to take advantage of them in physics education.
For junior high school where physics is mainly taught in a qualitative or semiquantitative way, I believe it will be possible to improve the treatment of several physical subjects by including computer programmes in the treatment. At this level it may often be profitable to make use of simulation programmes, but it is important to avoid making use of programmes simulating situations which could easily be studied directly. For example it would be a mistake to let students investigate the free fall only on a computer screen instead of studying real free falls. But a computer teaching sequence might be of help as part of a programme in which the students start by doing experiments with freely falling bodies.
Recently I have worked on developing computer programmes for the junior high school in cooperation with a Danish physics teacher, Sv. Wøjdemann, who is teaching at a school, where new educational ideas are developed and tested. So far we have developed three programmes, and tested them not only in his school but also in several other schools in different parts of the country. I think these programmes give a quite good understanding of our main ideas which can briefly be stated as follows.

The programmes shall:
a. be part of a general treatment of a physics topic.

b. stimulate the interest for and add to the general understanding of the topic.

c. stimulate thinking and reinforce learning.

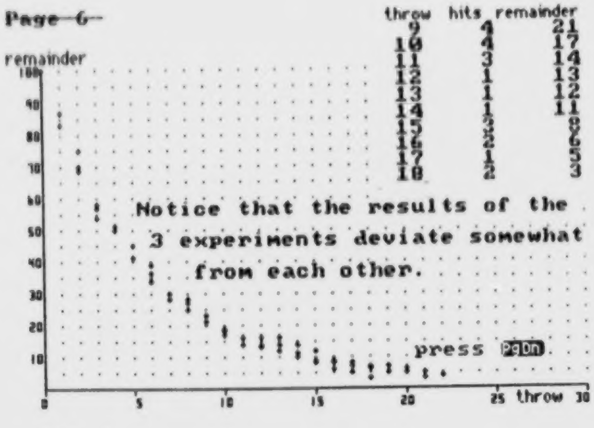
The first programme we developed is the programme "Radioactivity and Half Life". This programme is intended to be a part of a teaching sequence, in which the whole class start by finding the half life of a radioactive liquid extracted from a socalled mini-generator (radioactive Ba-137 with a half life of 2.6 minutes). With a Geiger counter the number of counts in 10 seconds is measured every 15 seconds. The decay graph is drawn and the concept of half life is introduced.
As students in junior high school do not learn about exponentials, the decay of the radioactive nuclei are compared with the results of an experiment in which the

students throw dice. They start by throwing 100 dice. The sixes represent decayed nuclei and are removed. Then the dice are thrown again and so on. The number of remaining dice is graphed as a function of the number of throws. It is shown that this graph is similar to the decay graph from the experiment with the mini-generator. In this way the students learn that the decay of nuclei may be explained as a probability phenomenon.

The weakness of this approach is that 100 dice is a small number, and that the analogy is not quite good, as the real decay graph does not show how the number of remaining nuclei decreases. A further treatment is therefore needed, and now the computer takes over.

The computer is programmed to work as a dice-thrower, where the outcome is shown in a table on the display and simultaneously plotted on the screen. Briefly the programme runs as follows:

1. It is shown that the computer works fast and produuce the same type of graphs as the ones the students know from their experiments with real dice. The students make three experiments, each time starting with 100 dice, and the result is plotted in different colours on the screen.



~~Page 6~~

throw	hits	remainder
9	4	21
10	4	17
11	3	14
12	1	13
13	1	12
14	1	11
15	3	8
16	2	6
17	1	5
18	2	3

Notice that the results of the 3 experiments deviate somewhat from each other.

Fig. 1

2. The students are asked to indicate the expected value of each throw. In practice they generally start by guessing but sooner or later they discover

that they just have to divide the remaining number of dice by 6.
When the right number is indicated, it is plotted on top of the three graphs from the previous experiments.

3. Three new throw-series are done starting with 10.000 dice, and the students observe that they now get three nearly identical graphs.

4. It is stated that the dice are thrown with an interval of 15 seconds, and the students are asked to find the half life.
Attention is drawn to the fact that a Geiger counter measures the number of decaying and not the number of remaining nuclei. Therefore the students are asked to make a new graph in which the number of decaying "nuclei" is plotted.

5. Now the students are told that the computer is able to throw dice with various number of sides (from 2 to 25), and they are asked to investigate how the half life depends on the number of sides.

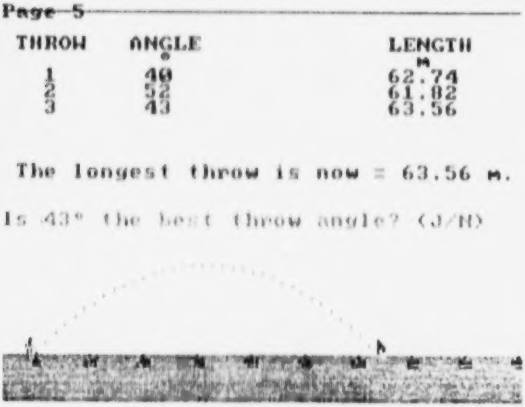
6. Next they are asked to write down the half life in the experiment with the mini-generator. The computer draws the corresponding graph, and they are now asked to find the number of sides of the dice, which fits the drawn graph best.

7. To ensure that the students have understood the connection between the number of sides and the decay-probability, they are finally asked to state how large a fraction of the radioactive Barium nuclei there will decay in 15 seconds.

The programme "Radioactivity and Half Life" illustrates how a computer programme can extend the treatment of a specific physical topic and reinforce the learning.

The programme "The Oblique Throw" first of all aims at stimulating the pupils' interest in the topic "motion" from the very beginning. It follows an activity in the sports ground, where the students investigate which factors decide the length of a ball throw.

As it is intended for 13 years old students the problems are described vividly in a story with three persons Robert Robot, William the Weak and Gunder the Gunner, who are throwing balls. The throws are shown on the display as indicated in fig. 2.



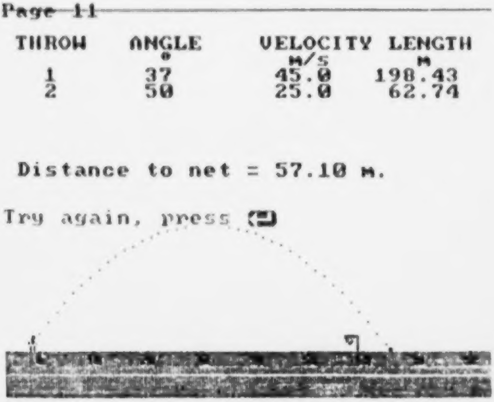
```
Page 5
 THROW   ANGLE               LENGTH
           °                   m
   1      40                 62.74
   2      52                 61.82
   3      43                 63.56

 The longest throw is now = 63.56 m.

 Is 43° the best throw angle? (J/N)
```

Fig. 2

The students have to find the best throw angle, and by changing the initial speed find the least speed needed to double the throw length. The programme ends with a basket ball game, where the students shall throw the ball into a basket placed arbitrarily by the computer at various distances (fig. 3).



```
Page 11
 THROW   ANGLE     VELOCITY  LENGTH
           °          m/s       m
   1      37         45.0    198.43
   2      50         25.0     62.74

 Distance to net = 57.10 m.

 Try again, press ⏎
```

Fig. 3

Even if this programme was developed with young students in mind it turned out that it also appealed strongly to grown-up people.

-o-o-o-o-o-o-o-o-o-o-o-o-o

The latest programme we have produced is "Satellites and Space Explorers". It is intended for use after the students have studied rocket propulsion and discussed the possibility of sending satellites in orbit around the Earth.
This programme contains the following options:

1. Placing satellites in circular orbits.

2. Satellites in synchronous orbits.

3. Manned space-ships.

4. Elliptical orbits.

5. The polar orbit.

6. Space explorers.

All students have to do option 1, and option 5 and 6 presuppose furthermore option 4.

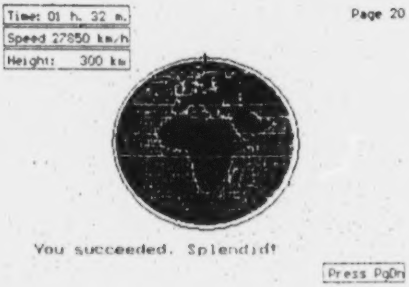
The computer is programmed to show the motion of a satellite launched at any given height with any given horizontal velocity.

In option 1 the students have to find the necessary initial speed to ensure a circular motion when the satellite is launched at a height of 2000 km and 4000 km. During the motion, time and speed are shown on the screen.

During this work the students experience how the shape of the path depends on the initial speed. When tested it gave rise to fruitful discussions on how the speed and the period would change when the height was increased.

In option 2 the students are asked to find the height in which a satellite follows the Earth's rotation. Here the students only have to suggest the height, and the computer will launch the satellite with the required velocity to produce a circular orbit.

In option 3 the students shall launch a satellite at a height of 300 km and give it an initial speed so that it remains between 275 km and 325 km. As all distances are shown in the right proportions the students get a good impression of how close around the Earth the satellites are moving (see fig. 4), and they experience how difficult it is to give the satellite the required speed.



Time: 01 h. 32 m.
Speed 27850 km/h
Height: 300 km

You succeeded. Splendid!

Fig. 4

In option 4 elliptical orbits are compared with the correspondant circular orbit and the students are asked to predict what happens to the period when the speed becomes larger than the speed needed for a circular motion. They check their prediction by doing experiments and they are asked to stop the motion of the satellite at the point of it's orbit where the speed is least.

In option 5 the students are asked to launch a satellite 40.000 km above the North Pole with such a speed that it will pass over the South Pole at a distance between 450 km and 550 km and compare the speed at the South Pole with the speed at the North Pole.

In option 6 the students are asked to launch a space probe at a height of 300 km and find the minimum speed needed to send it out in space.

The different options do not only engage the students in the solving of various problems connected with the launching of the satellites. They also contain useful information on the use we make of them in our daily life (radio- and TV-transmissions, meteorological observations and so on).

The experience we have got so far with the type of computer programmes I have described here are encouraging. We would have liked to distribute the programmes without charge to all Danish schools, but to cover the production costs it has been necessary to sell the programmes to the schools for a price which we try to keep as low as possible (250, 150 and 350 Dkr. IBM compatible).

They can be bought at Royal Danish School of Educational Studies **Institute of Informatics**
Emdrupvej 115 B, Copenhagen, Denmark Telefax 39 66 00 83

THE APPLICATION OF PHYSICS IN TEACHING ORAL RADIOLOGY

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The main reasons that oral radiology is taught is to enable dental students to produce technically good radiographs and to analyse them in a competent manner. The complete process of x-ray imaging, starting with the production of the x-rays, image formation, radiation protection of patients and staff, and ending up with a diagnosis, requires a good working knowledge of the physics involved, beside the necessary knowledge in the fields of anatomy and pathology. Therefore a basic training in radiation physics is given to dental students at the beginning of their oral radiology course.

At Gothenburg University oral radiology is scheduled into the dental studies curriculum during the 1st, 4th and 9th quarters. The relevant physics is integrated into these courses to improve understanding of the radiographic procedures. Figure 1 shows the aspects of radiation physics that are integrated into the main course (Borrman, 1989; Carlsson, 1975; Omnell, 1987).

The radiation physics course is essential and makes up the basis for understanding the principles and procedures of oral radiology. It is by no means to be treated as a separate subject, with the deep level of detail that would involve. A consequence of the integration is that the students' motivation towards reading radiophysics is increased because the reading of texts is combined with practical demonstrations. It is our belief that this motivation is further enhanced by the inclusion of clinical demonstrations in the teaching program. That can easily be done as the course is integrated. Also, an effort is made not to discourage the students with a heavy mathematical load as calculus is kept to a minimum and only the relevant topics in physics are considered (Holmberg, 1989).

The present report demonstrates with several illustrations the basic principles of object radiography. It mainly deals with the x-ray absorption process, exposure, photographic materials, sensitometry and the analysis of the radiographic image (see Figure 1).

RADIATION PHYSICS

Mathematical introduction : powers of x, exponential functions,
logarithms, graphical representation

Structure of matter : the atomic nucleus, the atom, electron orbitals

Electromagnetic radiation

Interaction between x-rays and matter :

- -photoelectric effect
- -scattering process (coherent, Compton)
- -absorption ($N = N_0 \exp(-\mu t)$)
- -physical and chemical properties of different materials

The x-ray apparatus :

- -x-ray tube parameters,
- -operation
- -production of x-rays
- -exposure factors (mAs, kVp, focus-film distance)

Dosimetry : instrumentation, exposure, absorbed dose

Health physics, radiation protection

Photographic materials and dark room procedure

Radiographic contrast : definitions, noise, sharpness

Sensitometry :

- -transmission $T = \phi_t/\phi_0$
- -opacity $O = 1/T$
- -density $D = \log(1/T) = \log(\phi_0/\phi_t)$

The radiographic image : different projections, clinical interpretations

Figure 1 Content of the integrated course in radiation physics.

The paper abstracted here presents an overview of the application of physics to oral radiology, outlining some concepts of teaching design, describing currently used examples applicable to dental radiography. All levels of teaching in dentistry rely heavily upon the use of cases to illustrate a point. In diagnostic radiology you try to detect and measure signals from the human body. After the establishment of the diagnosis the aim is to cure the patient. Therefore, it is important that the diagnosis is correct. The production of x-ray images has today been reduced to a routine procedure, however the introduction of more sophisticated techniques is unrelenting. In classical radiography, a three-dimensional object (all the anatomical details of a patient) is projected as a two-dimensional image onto a film. This means that you loose the dimension of depth, which in many cases would give important additional information.

Thus, the teaching of oral radiology includes both technique and interpretation components. Initially illustrations, anecdotes and analogies are used to build-up an overall picture. By the time more attention is focused on detail and logical analysis. The requirements and standards of the course should be clearly stated at the beginning of the course and it is important to point out the relevance of the course to the students' future work in dentistry. As ionizing radiation is hazardous to living matter, it is important that the students learn how to use this diagnostic tool to obtain maximal information with the minimum exposure to radiation to all involved.

When an object is radiographed it is important to know the background conditions. Anatomical structures in a clinical setting are generally known as far as their type and compostition are concerned. However, dimensions are different from one patient to the next. One example of this is when a piece of dry bone is radiographed, the exposure is reduced by approximately 50 per cent. Furthermore, according to White (1985) in order to produce equally dense radiographs using both 65 kVp and 90 kVp, exposure using the higher voltage must be reduced by 60 per cent. Moreover, approximately 20 per cent of the x-ray photons pass through the object to form an image on the film.

The primary x-ray beam passes through the jawbone and interacts with the matter of the object. At a certain level of exposure there will be variation in intensity, when the radiation passes through the object. This information is transmitted to the film to form the radiographic image. A schematic diagram of the situation where a round object and an object with sharp sides are radiographed is presented during the oral presentation. This example can be relevant to the clinical work, when small blood vessels and tumors are difficult to see, because the radiographer will only see contours when adjacent areas contrast sharply (Ratliff, 1972).

In a recent study by Pantoja et al. (1990), several examples were given of radiography of different objects. For example radiographs of two tomatoes were shown and interestingly the large "tomato" appeared to be less dense than the small tomato, due to the fact that the large "tomato" was only half a tomato. Similar principles were used when grapes and a "banana" were radiographed. The latter appeared more radiolucent than some of the grapes because only the banana peel was radiographed. These excellent examples are clinically relevant to lung disease diagnosis, because the situation is similar to that found in the chest wall and lungs. A search should be made for similar examples applicable to dental radiography.

As different restoration materials are continuously being introduced in dentistry, it is important that the students learn how filling materials can be indentified on the radiographs. In order to get some practical experience of these matters the students are asked to take radiographs of teeth with different types of restorations. Additionally, an aluminium step-wedge is placed on the films during the radiography so that the students can measure the density of the restorations and relate this information to the value on the reference step-wedge.

The students preferred mode of learning may depend on the nature of the task and on the student's own personal characteristics. A reading task does not itself make demands on the students. However, a problem-solving task requires the students to solve it while learning the details involved meaningfully. In many of the problem solving tasks a standard procedure can be used, which many of the students will adopt. This will sometimes mean that the students do not have to think at a deeper level, but this method is far better than the reading method without any problems to solve. In the oral radiology course the students may be asked to take different types of radiographs in order to better understand the principles of the physics involved.

The students consider what is required of them. They set priorities and begin to act. It is important that the teacher not only tells them what is required, but also what is important and the reason why certain facts are more important than others. Otherwise, the students may be too rational in selecting what they perceive as the minimal requirements. The students should be interested in learning for its own sake and be able to relate new information to previous knowledge. The teacher is of great help here because he/she links facts with real life and teaches the students to examine evidence critically and to form a framework for the facts.

The outline of the lecture will be reviewed in the following text. Before starting the lecture it is important to state the purpose of the talk. The aim of a presentation is that the audience should remember and understand the contents of the presented material. Oral radiology, like all test methods, is one of the tools in the process of producing a diagnosis. In order to make a diagnosis as correct as possible, it is important to obtain subjective-, and objective information as well as to examine the patient carefully and thoroughly.

To point out some of the obstacles in the way of the students producing good radiographs, some schematic examples are given of different types of interpretation problems that can arise when an image is observed and analyzed. The diagnostic process involves observing, describing, and understanding. Here it is important to stress, that what you finally see and use for diagnostic evaluation, is the result of many steps. "You will see what you expect to see"; is a commonly used phrase in this context. However, it is very relevant during clinical radiography. For example, if a patient arrives at your office in pain and points at a certain tooth, you will try to find something in that particular area on the radiograph that might explain the acute situation. It could be an increase in radiographic density or a decrease in density depending on the cause or the type of pathological condition. Thus, radiographs have different properties; radiographic density, radiographic contrast and radiographic detail.

The different radiographic appearance of teeth (animal and human) and pieces of bone are shown. X-rays passing through an object can be illustrated schematically with a cross-section of a tissue, total effective tissue mass in the beam and film darkening. The meaning of the words radiolucent and radiopaque are explained using examples; cavities, sinuses, non-metallic restorations and pulp chambers- and canals appear as radiolucent. In contrast, enamel, dentine, calculus and metal are seen as radiopaque. The difference between the low and high energy beams are explained by using arrows with short and long curves. Teeth with fillings are radiographed at 25 kV and 60 kV. The result with this change in kV is that the radiation beam of 25 kV will not penetrate the teeth and the restorations as well as that of 60 kV. An interesting effect of this is shown during the presentation. This example could also be an excellent laboratory exercise for the students during the course.

In order to make the material presented interesting for the students, a radiograph of a foot with a boot taken by Morton (illustration; 1896) is shown. This radiograph will again demonstrate the difference in radiographic density between metal and hard tissue. The advantages of radiography now becomes more obvious to the students. This is further illustrated by the radiographic examination of a mandible buried in a churchyard 400 years ago in Gothenburg. The toothgerms can be clearly identified and the age of the child was determined to be about 12 years. In another example, a dry skull found in the woods was radiographed. A bird's nest was found inside the skull.

X-ray diagnostic procedures require: good quality equipment, a good knowledge of normal anatomy/variation in normal anatomy and a good knowledge of pathology and differential diagnosis. Radiographs of the lower front teeth are shown to demonstrate the different appearances of restoration materials and the difficulties in caries diagnostics, due to the similarity in appearance of low contrast restoration materials.

As mentioned in the introduction, a radiograph is a two-dimensional image of a three-dimensional object. This fact is illustrated by a common clinical situation, when the anatomy of a third molar is determined. In this particular example a root-bending cannot be seen on the radiograph. The true anatomy of the tooth was studied after the operation.

A good knowledge of normal anatomy is mandatory, otherwise pathologic cases cannot be identified. To illustrate this, radiographs from a patient who earlier received irradiation to his right upper jaw is shown. As a result of the treatment, the roots of the teeth did not develop properly. In another example, a radiolucent fracture line of the mandible with only a small dislocation of the fragments is shown. Similar radiolucent lines can be seen, also in normal situations for example in blood vessels. Thus, again a sound understanding of the basic principles and clinical data will always improve the radiographic diagnosis. When bone is radiographed it is difficult to determine if there is a loss of mineral due to a pathological condition. It has been said by Worth (1969) that at least 30 percent of the bone must be absent in order to be seen on the radiographs. To demonstrate this a bone lid was made in a mandible. Radiographs were then taken with and without the lid in place. The thickness of the lid was about half the thickness of the mandibular bone. The radiograph with the lid in place appears more radiopaque than that without the lid.

The importance of a thorough analysis of the image-structure is pointed out by showing some illustrations of a man and a wood sculpture. The example is similar to some of the work made by the artist Escher (Locher, 1988). Constructions of angles of view of the "wooden box figure" suggests a unity, which is actually only a construction in the observer's mind.

As mentioned previously, evaluation of the anatomy and positions of third molars are common to the everyday work of the oral radiologist. Two radiographs taken at different vertical angulations show a tooth with a long root which is "divided" by a horizontal radiolucent line, representing the mandibular canal (alveolar nerve). However, there is a narrowing of the canal which indicates to the experienced observer that the nerve might pass through the roots. It was true in this case and the tooth had to be removed in several pieces in order not to damage the nerve supply of the mandible. Two photographs of a bird demonstrate the fact that it is important to observe an object from more than one angle, if you want to obtain maximal information about it from two-dimensional images. Photographs of the Faculty of Odontology-building also illustrate this very clearly.

A clinical situation also illustrates this fact, when a patient was referred to the department because of pain from the canine region of the maxilla, radiographs from two different angles were obtained. One of the radiographs indicated normal conditions, while the other radiograph showed a radiolucent fracture line of the canine tooth. Thus, good quality radiographs are required in order to obtain maximal and relevant information about the conditions in the oral cavity. This is further illustrated by two radiographs of the midline of the maxilla. Only one of the radiographs which is correctly taken will show an impacted tooth.

Additionally, it is important that the students learn how to take radiographs at different occasions in a reproduceable way so they can compare structures. A forensic case is demonstrated in which the frontal sinuses have a similar appearance in posterior-anterior radiographic views of the skull. This allowed the positive identification of a deceased individual.

References:

Borrman H (ed.) : Oral Radiology. Hand-out reading material for the students at the final course. Gothenburg University, 1989, p. 201 (in Swedish).

Carlsson C : Användning av logaritmer och exponentialfunktioner inom röntgendiagnostik. Linköping University LiH-RAD-R-025, 1975, p. 21 (in Swedish).

Holmberg P : Medical physics with a minimum of calculus. Symp. Problems of Interaction between Physics and Mathematics in Physics Education. Gdansk, Poland, 1989.

Locher J L (ed.) : The World of M.C.Escher. Harry N. Abrams, Inc., New York. 1988. p. 11.

Omnell K-Å : Odontologisk röntgenteknik. Almqvist & Wiksell Förlag AB, 1987, p. 88 (in Swedish).

Pantoja E, Kabler C and Li C P : Object radiography contrived to illustrate basic principles. RadioGraphics 1990; 10 : 323-340.

Ratliff F : Contour and contrast. Scientific American 1972; June : 91-101.

White S C and Goaz W : Oral Radiology; Principles and practice. S.W. Mosby, 2nd ed. Philadelphia, Toronto, New York, 1987, Chapter 2.

Worth H M : Principles and practice of oral radiological interpretation. Chicago. Year Book Medical Publishers. 1969, pp. 5-12.

PHYSICS AND TECHNOLOGY OF A SOLAR CAR (WITHIN PHYSICS EDUCATION AT A SWISS GYMNASIUM)

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***Summary:** Solar cars are popular in Switzerland. In special races they advertise as well solar energy as an alternative system of transportation. It is reasonable to make use of this positive bias for several purposes in physics education. The multiple possibilities of the subject are discussed within the context of a Swiss Gymnasium (High school).*

Some Remarks about the Swiss School System

The following facts about the age level 16 - 19 are important:

- 2/3 of an an age-class goes into an *apprenticeship* (mechanic: 4 years; cook: 3 years..)
- About 15 %, half of them girls, enter higher education. After graduation from the *gymnasium* most of them will go on with universitery studies.
- *Physics is a mandatory subject* not only in the scientific track of the gymnasium. Typical are three years with two lessons per week. The level in the scientific track is lower than in a German "Leistungskurs". But even in the other tracks most of the subjects are treated quantitatively, at the end even at calculus level.

Familiar Problems

Investigations[1] that have been carried out to find reasons for the lack of engineers showed that physics is the least appreciated subject. This frightening finding increased in the period from 1970 to 1984. A first analysis demonstrated the great difference between those who planned to go into engineering or sciences and the rest of the students. Those who planned to go on with the sciences rated physics second after mathematics. It is obvious that physics as it was taught to the 1500 students was *too much science oriented*. A second look[2] at the data displayed a significant sex difference. *Girls* expressed clearly that they disliked physics. They rated it much lower than mathematics and chemistry. This unambiguous signal confirms the finding of similar research in many other countries: Physics as it was presented didn't take into account the special interest of these young ladies.

In the autumn to come, the Swiss will be asked to vote on the future of nuclear energy. Although about 50 % of our electricity is produced by nuclear fission and no alternative is at hand, there is a fair chance that the shut-down of all plants will be accepted by the majority of voters. The obvious contrast between the dependence on technology and the unwillingness to accept the risks of e.g. large power stations or incinerators for chemical waste have given rise to the following question: What did the school do in order to inform youngsters on technology? It is obvious that because of the history of the gymnasium there is *no technology in its curriculum*.

Suggested Solutions

The Swiss gymnasium teachers association started an initiative to create what is called a *"framework curriculum"* [3] in order to stimulate educational innovations. This initiative was picked up by the educational authorities. They wish to align the 25 differing curricula of all cantons to have a good basis for discussions on coordination with the surrounding countries. By formulating and implementing new goals for physics - physics instruction as a part of a general education - the problems mentioned should be reduced.

One point is to introduce *new topics* that take into account the interests of girls and non-science students. Examples are: sports, medicine, geophysical problems, biographical elements, energy conservation and transportation.

Another point is to introduce a new style of communication between teachers and students. The student-centred *new methods* such as case-studies or projects are crucial. They will be accepted more easily by conservative teachers in connection with new topics. Even if they remain a minor aspect of the curriculum, they may stimuate pedagogical improvement.

The Topic "Solar Car"

Here, we consider an electrical car built of light materials which gets its energy from a photovoltaic device as a "solar car". This new combination of two well established technologies may be used in the curriculum for quite different purposes:

Realistic Examples in "Pure Physics"

Since the power of all electric cars is very limited (10 kW is already considered much) and the topography not completely flat, the famous inclined plane of ordinary *mechanics* can be discussed in a realistic example. But also simple questions of energy-storage, -transport and -conversion are available in a transparant situation. Unlike the combustion engine the electromotor may recover energy while the car runs downhill or slows down.

Three years ago the manufacturers stopped mounting the expensive solar cells on the cars, which may be parked in a dark parking-lot. Nevertheless they deserve the name "solar-car": More and more owners of electrical cars share large solar panels that are fixed in a suitable place and connected to the 50 Herz grid. They charge the batteries of their cars at their home. The complex topic of a *photovoltaic device* may be treated on different levels up to the question of solid state physics. It may even act as a starting point for the discussion of light quanta and an introduction into quantum theory. More advanced topics such as the self-inductance in the maximum power tracker may also be studied.

It is well known[4] that the batteries still form the main problem of electric cars. The Sodium-Sulphur battery, which was announced by ABB several years ago, is still under investigation since it suffers from a very poor life-cycle! This fact may lead to an interdisciplinary work with chemistry in the topic of *electrochemistry*. This subject was of great importance in the last century and doesn't seem very attractive today.

A Link to Technology

A simple look at the designs of so called "serie cars" which participate in the 1990 "Tour de Sol" shows one important difference between science and technology: In technology there are always *open questions*. E.g. What is the best way to place two passengers in a solar car? Technological possibilities offer *various solutions* which may be a maximum in one respect but are only an optimum in the overall view.

The interdependence between *technology and economy* is particularly obvious in a new field. However interesting such cars may be they will not dominate our urban traffic as long as they offer less comfort for a higher price. And the ordinary car will not disappear as long as no *political measures* are taken to make them pay for all ecological problems they produce (from pollution to the greenhouse effect).

Physics and Society

Very soon, such a discussion will become personal, which is attractive for students with strong social commitment but not of much interest in calculations. Those students will realise that it is difficult to find an answer to questions such as: *Can we rely on the sun?* The chioce is not only between: *How much mobility do we need?* but also: *How much knowledge of physics is necessary for the public?*

How to Introduce such Ideas into the Curriculum?

Administrative Preliminaries

In order to achieve these new aims it is urgent to *limit the mandatory content* of the physics curriculum. Talks between the physicists at universities and at the gymnasiums will take place next winter. Eventually, the educational administration will support such limitations. They will allow the teacher to select topics like the solar car and spend the necessary time on them without causing troubles for the future university students.

New detailed curricula will point to topics that are suitable to visualise connections with other subjects. Therefore a certain *crossover* e.g. between physics and chemistry or geography will take place. The administrations of the individual schools will have to be flexible with regard *of the time-tables,* which is necessary if two ore more teachers have to work together, get in touch with the industry, automobile associations etc.

Teaching Materials

Different kinds of teaching materials are being prepared or all ready in production. Among them are "guiding programms" for students and "teacher informations" on new topics. Especially interesting is a serie of *"case studies"* for the natural sciences. Up to this moment, only three examples (in biology, chemistry and geography) are complete.[5] Case studies in physics are: "electric car" and "energy from the sun". Another proposal is to build up a *databank* for problems of physics which are related to new topics.

Teacher Training

Teacher training must point out that primarily not the new technological connection but the *personal involvement of the student is important*. Since most teachers have little contact with and knowledge of technology, it must also become clear that *technology is more than a simple application of science*. Its creative aspect can be demonstrated e.g. by solar cars. Finally, teachers must become familiar with the demand for student centred teaching methods. And they must learn to *allow controversial questions* also in physics classes.

Striking the Balance:

Not all of the above mentioned problems can be tackled by implementing new topics, materials and methods. And there is an aboundance of criteria for good teaching to a wide spectrum of students! The following points indicate a positive judgement:

- Preconceptions	0	but a realistic system with energy flow in two directions
- Computer	0	but a model for complex optimisation
- Modern Physics	0	beside possibility to start with light quanta
- Technology	+	but in the immediate future not of great importance
- Problem Orientation	+	but the problem of energy storage remains unsolved
- Personal Level	+	but solar cars are not so common as videos ...

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[1] Häuselmann E.: Maturanden und Technik. Schweiz. Akademie der Technischen Wissenschaften, CH-8001 Zürich 1984.

[2] Kubli F.: Interesse und Verstehen in Physik und Chemie, Köln 1987 (Aulis)

[3] EDK: Rahmenlehrpläne für Maturitätsschulen. Schweizerische Konferenz der kantonalen Erziehungsdirektoren, CH-3001 Bern 1990.

[4] eg. Schmid W.: Physikaufgaben, Stuttgart 1987 (Klett).

[5] Frey K. (Ed): ETH-Fallstudien. Inst. f. Verhaltenswissenschaft, ETH Zentrum, CH-8092 Zurich 1990.

AN INTEGRATIVE COURSE AS A POSSIBILITY 0F DEVELOPING PHYSICS TEACHING

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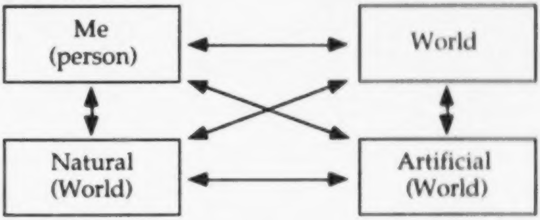
The latest school reform in Estonia starting from 1987 has referred to the necessity for integration on the content of education: "Including the integrative courses into the curriculum gives the basis for new Connections in the system of the students´ knowledge" (1). Still, some attempts towards integration have been made before, such as the connections between different subjects or the mechanical melting of different subjects together etc. We have to confess that those attempts have not carried to the real intersubject integration.

The mentioned tendencies have also had their influence on the development of science, including physics. Physics has been taught (and learnt) quite fragmentarily. Evidently, it may be one of the reasons why science, including physics, is not popular among the Estonian school students. The research data showed that in the years the percentage of our students disliking physics was growing from 15.1 to 25.5 (2). In the popularity list of all school subjects physics occupies one of the last places (2) . Since physics serves as a basis for almost all brances of technics (engineering and other technical sciences) the mentioned decline must make us quite cautious.

Another reason for the low estimation of physics may be connected with the subject–centered teaching. Physics has traditionally been taught in a science–centered way. Lately the need for humanizing of sciences has carried to a personality-(self–) centered education. The latter calls for the inquiries of the personality, his self-concept and his connections with the environment.

An attempt to integrate the students´ knowledge on the subject level was made by compiling the "Environmental Cource" in which physics is opened from a new viewpoint, through the psychological knowledge. The course is meant for the 9th Grade of the comprehensive school. Several notions and branches of physics used in this course have never been used in school physics.

The underlying conceptual principle of "The Environmental Course" is the unity of the World. There are four key-notions in the subject.



From these four words it is possible to form six different word combinations, each one appearing as respective chapter of the course.

The chapter "The Natural World" deals with the problems of cosmology, astronomy and physics. Here such terms as mega–, macro– and microworld are included and the information about the structure and the evolution of the universe is given. The descriptions of the reasons of the change of the seasons on the Earth, of enemical and biological processes are included in this chapter too.

In the chapter "The Artificial World" there is the material about the creation of the human being. It's the world of things, the artificial environment.

The chapter "Me and the World" deals with the relations between a person and the World, the history of the development of Man. Here the age of mankind is compared with the age of the Universe .

The chapter is a suitable place to speak about the possibilities of the World´s cognition. Man apprehends the World through his senses – there here the basis for optics and acostics is created. In his part we speak of the cultural influence in the development of Man.

But It´s important to speak about the society as of one part of the environment. While connecting the notions "Me", "The natural world" and "The artificial world" we may show the to sides of Man – the social and biological ones.

The last part of the course is build up by contrasting of the natural and artificial worlds where the emphasis is laid on the pollution of nature and of its negaive influence on Man.

1. Main principles of education in Estonia. /Comp. by E. Kareda, V.Kornel and others. – Tallinn 1989.

2 A. Saar, J.Hendre. Physics and technology in students' opinion. – In: Basic Principles of School Technology. Report PATT-3 conference. – Eindhoven, 1988, vol. 2, pp. 379–383.

ASPECTS ON INTERDISCIPLINARY PHYSICS TEACHING

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Teaching physics to students who combine a knowledge in physics with some other main discipline should be performed in a different way from the teaching process to students majoring in physics. The need of a different approach arises when considering background knowledge in physics and the motivation among students towards studying physics.

At the University of Helsinki students read physics as a major discipline at the Faculty of Science and Mathematics. Shorter physics courses with a professional orientation are also given at other faculties, for instance at the Faculty of Medicine, in the form of a course in medical physics.

Most of the students at the university have passed entrance tests and before that they have completed the 3-year "gymnasium" (higher secondary school). Those majoring in physics and medicine at the university have usually chosen the advanced physics course at the "gymnasium". The advanced physics course consists of 8 periods, compared to only 2 periods for the general course in physics. It is not even obligatory to read physics at all at the "gymnasium" level. However, the entrance tests are based on the curriculum of the advanced course and most students further prepare themselves for the tests by reading extra and taking part in special preparation courses. In that way a possible deficient knowledge in physics can by corrected (Holmberg, 1989 a,b).

In figure 1, the procedure is shown. Different entrance tests lead to different major subjects. It takes approximately 5 years to reach the final examination at the university. In figure 1 we also indicate the position of the physics courses in the curriculum. Those reading medicine take a short course (3.2 weeks; 40 h/week) in physics during the second half of the first year. This brief course in medical physics and radiation physics should give the knowledge in physics necessary for further successful medical studies. Major subjects that will benefit from physics are physiology, radiology and radiation therapy, but also medical chemistry and other subjects will need a thorough knowledge in physics. The knowledge obtained during the short course in medical physics will be applied to medical problems later during the entire period of studying medicine (approx. 5 years).

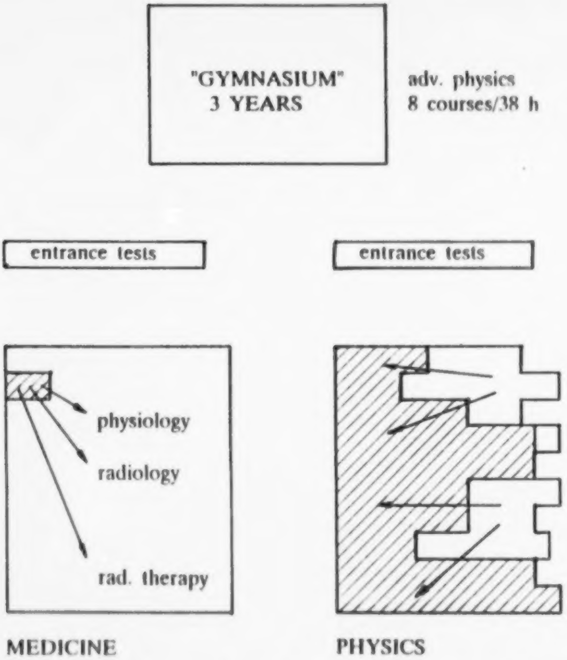

Figure 1 Physics is read in the "gymnasium" and is part of many entrance tests. The position of physics is also indicated (shadowed areas) in the curriculae of medicine and physics (read as a main subject).

Looking at the curriculum for those majoring in physics, a different picture is obtained in figure 1. Now massive courses in physics dominate the curriculum, interrupted only by short periods of other subjects, necessary for the understanding of the main courses. The paths of applied knowledge are now reversed, in comparison to the medical curriculum, and the students are concerned full-time with the main subject: physics. Therefore, the motivation towards reading physics and also applied courses is high.

The motivation among the students in the two groups is quite different. Those majoring in physics have voluntarily decided to study physics; therefore it may be assumed that they are satisfied with the situation given in figure 1. The medical students, on the contrary, do not always see the benefit of the intensive course in medical physics. They have been approved to the Faculty of Medicine to study medicine, not to read physics. They have already been tested several times in physics: at the "gymnasium" and in the entrance test, so they wonder why it is necessary to read physics again. They fail to see the course in medical physics as an applied course, the content of which has not been lectured earlier. Therefore, motivation is low.

However, problems arising in teaching an integrated physics course diminish when

- a minimum of calculus is used;
- practical examples are explained;
- clinical routines are demonstrated.

Different formats of the course in medical physics, and also other courses with an applied viewpoint, can be used, including lectures, exersises, laboratory work and clinical demonstrations, as in figure 2. As the course proceeds from theory (lectures) to practice (clinical routines), the motivation of the students increases rapidly (Holmberg, 1989 c).

In table 1 the content of a course in radiation physics for medical students is outlined. As can be seen, only the most relevant parts of a general course in radiation physics are dealt with in the educational program of medicine. Large areas of pure physics are omitted, such as the extra-nuclear structure of the atom dealing with optical spectra and electron distributions, the relationship between magnetic moment vectors and angular momentum vectors, the Zeeman effect and the Stern-Gerlach experiment. A more complete part of nuclear physics should further include binding energies of nuclei, nuclear energy in the form of fission and fusion, nuclear reactors, cosmic rays, elementary particles and high energy physics, different types of accelerators, etc.

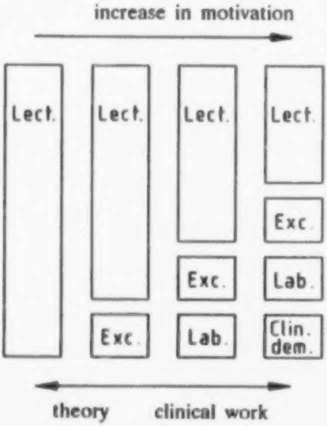

Figure 2 Different course formats. As the course proceeds from theoretical presentation (lectures) to clinical work, the motivation increases.

TABLE 1 CONTENT OF THE COURSE IN RADIATION PHYSICS

Atomic and nuclear physics :
  - a basic knowledge

Radioactivity :
  - radioactive decay
  - half-life (physical, biological, effective)
  - series decay
  - Tc-generator

Interaction between radiation and matter :
  - different types of radiation
  - modes of interaction
  - detection of radiation
  - scintigraph and gamma-camera

X-rays :
  - x-ray tubes
  - x-ray spectra
  - kVp, mA, s

Diagnostic radiology :
  - radiological picture
  - tomography
  - CT

Nuclear medicine :
  - isotopes
  - statical investigations
  - dynamic investigations
  - radiation dose

Radiation biology :
  - biological effects
  - cell survival curves
  - radiation therapy
  - radiation protection

In the medical course more practical aspects are considered, such as the formation of the radiological picture, different imaging techniques, the use of isotopes in medicine and radiation biology and protection (Holmberg, 1987, 1988 a).

In general, physics teachers tend to be too ambitious. The course they teach consists of a fixed amount of hours/lectures, and during that time they try to teach "everything", i.e., they try to give the students as much knowledge as possible in pure and detailed physics. They do not always remember that that is an impossible task. An alternative would be to use a little less time on pure physics, and to use the remaining time to increase among the students the motivation towards reading physics and to create a real interest in physics.

Only some 0.05 % of the population in an industrialized country are physicists. Therefore, the teaching of physics to non-physicists should be "extroverted", i.e., the teacher should take examples from every-day life known to everyone, and explain the phenomena in terms of physics. Only then does physics become a reality to the students (Holmberg, 1988 b).

In teaching applied physics one should concentrate on basic principles, and give the students a firm base of physical understanding from which they can jump to higher levels. In figure 3 is given the path of problem solving (Holmberg, 1989 c). The solving of the fundamental equations put up often causes problems,

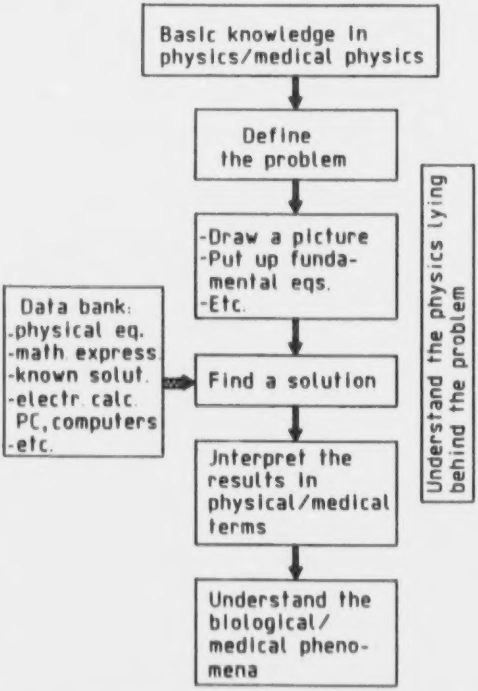
Basic knowledge in physics/medical physics
Define the problem
-Draw a picture
-Put up fundamental eqs.
-Etc.
Data bank:
-physical eq.
-math express.
-known solut.
-electr. calc.
PC, computers
-etc.
Find a solution
Interpret the results in physical/medical terms
Understand the biological/medical phenomena
Understand the physics lying behind the problem

Figure 3 The path of problem solving in physics. Non-physicists can use data banks to find the solutions to mathematical expressions. The understanding of the phenomena and the interpretation of the results is more important than a detailed mathematical analysis.

since advanced calculus is needed. The teaching procedure of medical physics (or some other branch of applied physics) may, at this point, use different data banks : ready solutions to standard equations, tables and handbooks, PC:s and computers, etc. The exact mathematical treatment of the problem is not essential. It is of greater importance that the problem be defined, and that the results can be interpreted correctly in physical/medical terms. The students should understand the biological/medical phenomena and the physics behind the problems.

References :

Holmberg P : The use of audio-visual methods in radiology and physics courses. Nucl. Instr. Meth. Phys. Res. 1987; A255 : 380-383.

Holmberg P : Teaching radiation physics and radiation protection to medical students. Radiation protection practice, Vol. III, p. 1550-1553; 1988 a. Seventh Int. Congr. Int. Rad. Protect. Assoc., Sydney, 10-17 April, 1988.

Holmberg P : Extrovert fysik. Dimensio 1988 b; 9 : 49 (in Swedish).

Holmberg P : Basic knowledge in mathematics and physics among students entering university. Symp. Problems of Interaction between Physics and Mathematics in Physics Education. Gdansk, Poland. 1989 a.

Holmberg P : Opiskelijoiden valinta lääketieteen koulutuslinjalle Helsingin yliopistossa 1988. Suomen Lääkärilehti 1989 b; No. 6 : 529-531 (in Finnish).

Holmberg P : Medical physics with a minimum of calculus. Symp. Problems of Interaction between Physics and Mathematics in Physics Education. Gdansk, Poland. 1989 c.

DIFFICULTIES IN PHYSICS TEACHING

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ABSTRACT

A few studies performed by the University of Washington Physics Education Research Group on student learning difficulties are described,with specific illustrations being taken from different subject matter areas such as mechanics, electricity, and optics. Implications of these studies with respect to instructional difficulties faced by all teachers in instructing different student populations are discussed together with implications concerning the teaching of future teachers.

Paper prepared for presentation at the International Symposium on the Evaluation of Physics Education, University of Helsinki, Helsinki, Finland, 25 - 29 June 1990.

Difficulties in Physics Teaching

1. Introduction

Although, later in this paper, I shall give specific examples of student difficulties that stand in the way of both teaching and learning, I wish to start with the statement of several broader generalizations that emerge from our observations. I refer to these as some of the "facts of life" of which we must continually remain explicitly conscious in our teaching:

(1) One fact of life is that there is a serious fallacy associated with a tendency on the part of members of professional groups such as the one I am now addressing (scientific professionals with sophisticated grasp of both abstract modes of reasoning and of subject matter in their respective fields) to extrapolate their own experiences of learning and intellectual development to all other learners. Time and again, I hear my colleagues saying, "Why *I* learned and understood it *this* way," implying that students should easily be able to follow in the same track.This extrapolation is, in fact, applicable to only a very small percentage of students (namely, those who are likely to become professionals like us and who progress more or less spontaneously) and is not valid for the great majority of children and adults with whom we must still be concerned in science education. It is necessary to ascertain the actual empirical facts concerning learning difficulties and concerning levels of command of various concepts and modes of abstract logical reasoning in any given group we teach and to refrain from assuming that our own personal history of learning is automatically applicable to everyone else.

(2) A second fact of life is that purely verbal inculcation, however lucid, has very little effect in developing abstract reasoning and concept formation in the majority of learners. This is not to disparage clear explanation and exposition; it would be foolish to advocate unclear explanation or none at all. Too many teachers, however, labor under the illusion that clear explanation is all that is necessary in good teaching, and this illusion is a significant source of student failure to progress toward genuine understanding rather than taking refuge in memorization of end results and procedures. Not only is hands-on experience an essential part of real learning, but students must also be led to articulate explanations, interpretations, definitions, and lines of reasoning in their own words. They must have the opportunity to interpret their own observations and hands-on experience, and they must be able to define new technical terms *operationally*, that is, through appeal to shared experience and simpler words

having prior definition. Passive listening to lectures, however lucid, does not, by itself, produce the understanding which we invariably announce to be our educational goal.

(3) Still another fact of life is that very few individuals master concepts and lines of reasoning on a first exposure regardless of whether they are children or adults. Development of mastery and understanding comes to most individuals only with repeated opportunity to apply the concepts or engage in the reasoning , and the repeated opportunities must be spaced out in time and must be applied in altered and increasingly rich contexts. (Rapid "remedial" sessions, using artificial materials rather than the real subject matter under consideration, and meant to bring the learner quickly into control of something that should have been mastered earlier, are useless and produce no lasting effect.) This implies the necessity of continually "spiralling back" to allow repeated encounter with the concepts and reasoning as one proceeds in study of the subject matter. Stopping and belaboring one concept (say, velocity) without going on to a next one (say, acceleration) until the first is fully mastered is also useless. One must keep on going toward richer and more rewarding contexts while generating repeated opportunities for spiralling back. In this context, I discern what I call a "Second Law of Instruction," analogous to the Second Law of Thermodynamics: just as one cannot convert a given quantity of heat entirely into work, so one cannot lead 100% of a group of learners to mastery of a concept or line of reasoning on a first encounter. One reaches a few students the first time, a few more the second, and keeps adding individuals with each encounter after *elapsed time* and in *altered and enriched* context. Our experience has been that, in many instances, it takes five or more such re-encounters before the great majority of the students have achieved the insights being sought.

(4) Finally, there is the observed fact that, if an individual has not yet mastered a concept or line of reasoning that might perfectly well have been mastered at some earlier age such as 13, 7, or 11 and comes to the learning *de novo* as an adult, the learning, for most individuals, takes place at about the same rate as it does in the child, with confrontation of the same hurdles and obstacles and with overcoming of the same pre- or mis-conceptions. The fact of greater maturity, unfortunately, does *not* speed up the learning, however much we wish it might. In fact the learning is frequently *slower* in the adult, largely because of

> the interfering effect of un-understood vocabulary and technical terms that have been assimilated over the years. (That adults do not break through any more rapidly on such learning than do children enters our operations in a most vital way when we confront the problems of teacher education. Unawareness of this fact has been responsible for most of our failures in the U.S. at the remediation of in-service teachers.)

The "facts of life" that I have listed above underlie all my own thoughts concerning the approach to teaching science to children as well as to adults who have not had adequate prior exposure to the ideas under consideration and are approaching the necessity of genuine understanding for the first time. My forthcoming specific illustrations will probably be clearer if these underlying thoughts are kept in mind. I am afraid that some of the facts I have asserted are unwelcome and that you might not want to hear them. All I can do is assure you that careful observation and listening to what learners of all ages actually *say* (instead of just giving them lucid explanations) substantiate what I have asserted. It lies at the heart of our activity as scientific professionals that unpalatable truth is preferable to cherished error, and I seek to apply this tenet to our educational insights as well as to our scientific research.

2 Arithmetical Reasoning with Ratios and Division

Student difficulties with all kinds of ratio reasoning (simple proportional reasoning; word problems involving interpretation and use of division; scaling and functional reasoning using ratios rather than substituting in formulas) have been documented and described by McKinnon and Renner (1971), Karplus, et al (1979), Arons (1976, 1983), Chiappetta (1976), and many others. Stevenson, et al (1986) document superior levels of arithmetical achievement of Chinese and Japanese children relative to American children, while Karplus, et al (1979) found little difference between European and American 13 - 15 year-olds.Serious difficulties with such reasoning, however, arise in a significant portion of virtually every student population. A large proportion of American college students in engineering physics courses, for example, exhibit severe deficiency in their ability to deal with ratio reasoning in geometrical scaling or in functional relations involving direct or inverse powers (greater or less than unity) of an independent variable, and many American college students in non-calculus physics courses (students preparing for study of architecture, medicine, pharmacology, etc.) exhibit inability to deal with word problems involving density, concentration, composition, rates of change, and so forth. Fewer than 10% of American elementary school teachers seem to be secure with word problems, and those who are insecure avoid requiring students to deal with such problems in their school work.

There is a difficulty here for both students and teachers, but the difficulty is not insuperable. The great majority of students can be helped to overcome these deficiencies through *repeated* practice. Such practice must include the opportunity for each student to explain the line of reasoning in his or her own words. They must be led to interpret ratios such as mass M in grams divided by volume V in cubic centimeters as giving the number of grams in *one* cubic centimeter. (The failure to bring out the word "one" explicitly in explaining the meaning of the ratio underlies much of the difficulty students have with such reasoning.) The practice must take place within the subject matter of the physics course itself, must be spread out over time, and must be successively invoked in altered, increasingly rich context. Preliminary, rapid remedial exercises in artificial context are ineffective.(I have written quite extensively about dealing with this learning problem. Those interested in pursuing this issue in more detail should see my recent book, Arons (1990)).

Student difficulties with all the different forms of ratio reasoning can and should be remediated prior to college-university level. This can be accomplished, however, only by making sure that school teachers have developed the necessary capacities and security themselves: they should be able to do the reasoning and explain it clearly in their own words; they should be keenly aware of the existence of the difficulty among students and should be capable of identifying those students who have gained control of such reasoning and those who have not; they should be able to devise questions and problems that induce fruitful practice of ratio reasoning in any relevant subject matter.

3 Kinematics

Many useful insights are being developed concerning widespread, and hitherto poorly perceived, student difficulties in forming concepts of position, instant, velocity, acceleration, and in misconceptions concerning everyday gravitational phenomena.

[Trowbridge and McDermott (1980), (1981); Gunstone and White (1981); Peters (1982); Arons (1990).]

Numerous difficulties are superposed in this area: failure to assimilate clearly articulated operational definitions and attendant failure to separate the underlying idea from the technical name [Arons (1990)]; confusion between "protoconcepts" of position and velocity and of velocity and acceleration [Trowbridge and McDermott (1980), for example, report protocols in which students insisted that two objects had the same velocity when one was clearly passing the other]; difficulty with translation of verbal descriptions of an object's motion into a graphical representation [McDermott, et al (19870]; failure to possess meaningful operational definitions of "vertical" and "horizontal"; belief that gravitational effects vanish in the absence of air (i.e., that objects no longer fall when air is not "pressing down on them"); belief that an object nearer the ground is "heavier" than an identical, balancing object higher above the ground (under conditions of small, human scale, distances in which differences of gravitational force with elevation would be completely unobservable) [Gunstone and White (1981)].

Teachers, in particular, should be made explicitly aware of these beliefs and difficulties and should see that the questions, demonstrations and requirements for purely qualitative phenomenological thinking -- that revealed the difficulties and misconceptions in the first place -- are themselves instructive exercises that help students confront contradictions and inconsistencies and thus help resolve the misconceptions and confusion. All teachers should be encouraged to invent additional phenomenological questions of this variety so as to increase the existing collection. (Such questions, for both homework and testing, are in very short supply and are rarely to be found in textbooks. The latter tend to concentrate on numerical exercises rather than on phenomenological thinking and reasoning.)

4. Understanding the Law of Inertia

Because of the obvious conceptual importance of the subject matter, the preconceptions students bring with them when starting the study of dynamics, and the difficulties they encounter with the Law of Inertia and the concept of force, have attracted extensive investigation and generated a substantial literature. A sampling of useful papers, giving far more detail than can be incorporated into this discussion, is cited in the bibliography. [Viennot (1979); McCloskey, Camarazza and Green (1980); Champagne, Klopfer, and Anderson (1980); Gunstone, Champagne, and Klopfer (1981); Clement (1982); di Sessa (1982); White (1983); McDermott (1984); Halloun and Hestenes (1985).]

Learners' difficulties in encompassing the Law of Inertia and the concept of force stem, in large measure, from the wealth of common sense preconceptions and experiential "rules" that most of us assimilate to our view of the behavior of massive bodies before we are introduced to Newtonian physics. Some of these views are Aristotelian, e.g. the necessity of continued application of a push to keep a body moving. (It is very difficult to abandon thinking of rest as a condition fundamentally different from that of motion, or to accept the view that, rather than asking what keeps a body moving, we should ask what causes it to stop.) Many of these common sense views, however, are more closely related to the medieval notions of impetus associated with philosophers such as Buridan and Oresme.

All investigations show these "naive" preconceptions to be very deeply entrenched and very tenaciously held. It is important, therefore, for teachers to understand that such student difficulties are not reflections of "stupidity" or recalcitrance. The difficulties are rooted in seemingly logical consequences of perceived order and experience and are vigorously reinforced by insistent use (or actually, misuse) of words drawn from everyday speech (inertia, mass, force, momentum, energy, power, resistance) before these words have been given precise operational meaning in physics. Persistent misuse of the terms in thinking to oneself and in communicating with others is a major obstacle to breaking away from the naive preconceptions. (This is another reason for helping students stand back and become very self conscious about the process of operational definition -- term by term.) Some teachers tend to minimize such problems by characterizing them as "merely" a matter of language or semantics, apparently not realizing how formidable and significant these linguistic aspects tend to be.

Investigations of understanding of the Law of Inertia further show that it is far from sufficient to inculcate the law verbally and supplement it with a few demonstrations of the behavior of frictionless pucks on an air table or of gliders on an air track. Many students will memorize and repeat the Law of Inertia correctly in words, but, when confronted with the necessity of making predictions and describing what happens in actual physical situations, they revert repeatedly to the naive preconceptions and predictions, giving the disappointed teacher the sinking sensation of not having succeeded in teaching anything at all.

If one wishes to lead a majority, rather than a small minority, of students to understanding of the Law of Inertia, one must accept the necessity of providing a wide array of experiences, both hands-on and hypothetical, in which students make their own errors, encounter the resulting contradictions, and, forced by these errors and contradictions, revise their preconceptions. Such experience cannot be provided and mastery developed, however, in one short remedial session. The ideas and initial experiences should be introduced while development of the subject matter is continued without waiting for full mastery on first encounter. One then helps cultivate mastery and understanding through repeated spiralling back to qualitative application of the Law of Inertia in increasingly rich and sophisticated physical situations as the study of the science continues. [For more detailed discussion of specific techniques of such instruction see Arons (1990)].

5 Phenomena That Elude Direct Sense Perception

One of the most basic examples of student difficulty with phenomena that elude direct sense perception is the tenacious resistance of many students to accepting the notion that, when a book rests on a table, the table exerts an upward force on the book. An initial primitive stage is one in which students believe that forces can only be exerted by animate objects, but, even when this preconception is overcome by appeal to the action of springs and results of collision between inanimate objects, many students still resist the idea that seemingly rigid objects (such as the table) are capable of exerting a force on another object. For more detailed discussions, see Minstrell (1982).

Investigation shows that this resistance is not overcome through assertion and explanation by the teacher, however lucid the exposition and argument may be. Conviction and acceptance develop only after slow and patient discussion of various thought experiments and direct observations. Among these are: interpretation of what one feels personally as increasing load is placed on one's hand; visualizing what happens when one puts objects on beds, soft chairs, and very soft springs; "bridging" between the very soft cases and the hard table by placing the book on a foam pad and on increasingly stiffer pads; visualizing what happens to the table as the load placed upon it increases to the point at which the table itself breaks; making an optical lever by reflecting a beam of light from the table surface to a wall and having students observe the deflection of the light beam as load is applied to the table; leading students to the ultimate perception that some finite deformation of the table must occur under any finite load however small, i.e. leading them to understand that the table must be deformed when a sheet of paper is placed upon it, even though the resulting deformation completely eludes our direct sense perception.

A serious deficiency in much present day physics instruction resides in the fact that students are generally not led to visualize details of various processes they cannot see directly. As a result, they frequently fail to understand the most basic phenomena, and they concentrate on problem solving procedures without developing physical insight into the phenomena dealt with in the problems.

In addition to the deformation of the seemingly rigid table under loads however small, there are many other important situations in which similar visualization should be cultivated. The capacity for such visualization develops only rather slowly and only after opportunity for practice in a wide variety of contexts, gradually increasing in richness and sophistication. Following is a series of examples of such situations. However disparate these situations may initially seem, they are all unified by the theme of visualizing physical effects that transcend direct sense perception.

(1) Visualizing the deformations taking place in collisions between objects.

(2) Visualizing the variation of tension in an accelerated, massive rope or chain.

(3) Visualizing the mechanism of the setting up of stresses associated with temperature changes. (e.g., the tension set up in a rod, clamped at its ends, as it cools after being heated; the breaking of a strong container in which water freezes, etc.)

(4) Visualizing the bouncing back and forth of the longitudinal compression wave in a very long rod when one end of the rod is pushed. Students should be led to comprehend that the far end of the rod is *not* displaced at exactly

the same instant that force is applied to the near end. It is the extremely short time interval that they are reluctant to accept and visualize.

It must be emphasized that the phenomenon involved in item (4) is far from special or trivial; it has, indeed, a very deep connection to underlying concepts, laws, and physical theory. During the interval that elapses between the push on the near end of the rod and propagation of the compression wave to the far end, the force exerted on any object at the far end of the rod is *not* equal and opposite to the force exerted by the rod on our finger. In other words, Newton's Third Law breaks down over the intervals of time and distance involved between the ends of the rod, and the associated "action-at-a-distance" theory becomes invalid if applied over these intervals. In this instance the Third Law is, of course, still valid if applied layer-by-layer through the material, and momentum and energy are conserved by virtue of the wave propagation. It is such failure of action-at-a-distance theory that leads to recognition of the limited validity of Newton's Third Law and finally gives primacy to the Law of Conservation of Momentum.

In the latter years of his life, Michael Faraday persistently asked questions as to whether or not there was a process in space that mediated electric and magnetic interactions: If one of two interacting charged particles is suddenly displaced, does a finite time interval elapse before the force on the second particle changes? Does a finite time interval elapse between the instant an electric current is initiated in a wire and the instant a neighboring compass needle begins to swing in response to the magnetic effect of the current?

If a finite time interval does elapse in such phenomena, electric and magnetic effects cannot involve action-at-a-distance. What happens in the intervening space? To incorporate the possibility of the existence of finite time intervals, Faraday invented a model, a visualization completely transcending any direct sense experience -- the famous concept of "lines of force" that stretched, contracted, spread apart, and pulled together, propagating electric and magnetic effects through empty space. All Faraday's attempts to measure a finite time interval failed; the technology of the time was not ready for so difficult an experiment. But James Clerk Maxwell took up Faraday's notion of lines of force, eventually creating field theory as we know it today.

Starting with the apparent rigidity of tables and long rods, going on to the perception that all matter is subject to deformation, and invoking Faraday's questions as to the elapse of finite time intervals in electromagnetic phenomena, students can be led to at least a rudimentary insight into the failure of action-at-a-distance theory, how it is that primacy comes to be accorded the conservation laws, and why field theory was invented. And this can be done well before it becomes appropriate to set up and solve Maxwell's equations. As a matter of fact, it can help make field theory far more intelligible and acceptable to the students.

Research strongly suggests that the modes of thought described in this section help students synthesize, organize, and perceive unity in a wide range of apparently unrelated concepts and phenomena. This perspective must be cultivated in teachers before it can be successfully conveyed to students.

6 Illustrations from Electricity

As pointed out in Section 4 on the Law of Inertia, students come to the study of Newtonian mechanics with deeply rooted *pre* -conceptions regarding force and motion. These preconceptions stem principally from intuitive perceptions based on everyday kinesthetic experience with motion of familiar objects, and familiar vocabulary is forced to accord with these preconceptions. Our concepts of electricity, however, are based on careful observations of phenomena that are not part of everyday kinesthetic experience and are built on abstract models that derive from these observations.

Since the majority of our curricular materials (at secondary school and university level in the U.S.) tend to assert the end results as though the basic electrical concepts were obvious and understood by all, students come to the study of electricity with little or no concrete experience but with exposure to an extensive technical vocabulary that has not been based on careful or adequate operational definition. The consequence of such pedagogy is that the majority of students in introductory physics are imbued with a variety of verbal *mis* -conceptions that seriously impede the development of genuine understanding of electrostatic phenomena and of simple electrical circuits. [Fredette and Clement (1981); Arons (1982) and (1990); Cohen, Eylon, and Ganiel (1983)]

Although students may emerge from introductory physics courses with the capacity to solve routine textbook problems applying Coulomb's Law, Ohm's Law, or the

Kirchhoff Laws, investigation of their actual knowledge and understanding reveals that many students:

(1) Do not understand what is meant (and what is *not* meant) by "electrical charge," many tending to regard it, in a seventeenth century mode, as some kind of imponderable substance.

(2) Have no clear operational idea of what is meant by "like" charges, believing that the statement that "like charges repel" defines the concept of "like."

(3) Cannot cite the evidence that leads us to believe that there are no more than two varieties of electrical charge.

(4) Cannot describe observations indicating the mobility of electrical charge on some materials and not on others, observations that compel the invention of the concepts "conductor" and "insulator."

(5) Cannot cite observational evidence showing that phenomena taking place in a system consisting of a voltaic battery and metal wires are in any way related to the phenomena observed with rubbed materials, pith balls, and electroscopes (i.e. cannot cite evidence of commonality among these two classes of phenomena and thus justify calling both classes "electrical.")

(6) Cannot cite observational experience leading to invention of the concepts "electric circuit" and "electrical resistance."

(7) Fail to understand that electric charge is not "used up" in an electric circuit.

(8) Fail to have any valid understanding of "potential difference."

(9) Do not understand what is meant by "short circuit."

(10) Have no understanding of the energy transformations occurring in a simple dc circuit.

All of the above disabilities are documented in the references cited. Additional gaps in understanding are illustrated in performance on the following problem which I administered in a first year university engineering-physics course after the class had begun dealing with dc circuits using Ohm's Law and the Kirchhoff Laws. The problem was presented on an "open book" basis, i.e., students were free to refer to their textbooks while working on the problem.

Problem: In the circuit shown in Fig. 1, the battery maintains a constant potential difference between its terminals at points 1 and 2.(i.e., the internal resistance of the battery is to be considered negligible.) Three identical flashlight bulbs A, B, and C are screwed into their sockets and are lighted when the circuit is closed. After each of the changes suggested in the following questions, the system is returned to the initial condition shown in the figure before the next change is made. The question "What happens to ... ?" refers to whether the quantity in question increases, decreases, or remains unchanged. Indicate your reasoning briefly in answering each question.

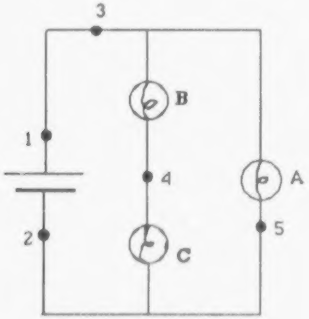

Figure 1

(a) How do the brightness of the bulbs A, B, and C compare with each other in the initial condition?

(b) What happens to the brightness of *each* of the three bulbs when bulb A is unscrewed and removed from its socket? What simultaneously happens to the current at points 3, 4, and 5?

(c) What happens to the brightness of *each* of the three bulbs when bulb C is unscrewed and removed? What simultaneously happens to the current at points 3, 4, and 5?

(d) What happens to the brightness of *each* of the three bulbs when a wire is connected from the battery terminal at point 1 to point 4? What simultaneously happens to the current at point 3? What simultaneously happens to the potential difference across bulb B? What simultaneously happens to the potential difference across bulb C? What simultaneously happens to the potential difference between points 1 and 5?

(e) What happens to the brightness of *each* of the three bulbs and to the current at point 2 if a wire is connected from the battery terminal at point 2 to the socket terminal at point 5?

Prior to confronting this problem, the class had been doing the conventional end-of-chapter homework problems, and had not had exposure to qualitative questions of this kind. The class average on a typical numerical problem using Ohm's Law was near 70%. The class average on the above problem was under 30%. Very few students had anything correct in part (d), and some very astonishing changes were predicted by many students in part (e). After having the opportunity to think about questions of this kind (some students even went on to play with their own battery and bulbs circuits), the performance on such questions rose to over 70%.

In other words, such investigations show that, regardless of ability to solve conventional end-of-chapter problems, many students (even in calculus based engineering-physics courses) have failed to develop significant phenomenological understanding of electrical concepts or electrical phenomena. Since most our teachers in the U.S., especially those working at pre-university levels, have been taught in the conventional manner, many emerge with at least some of the deficiencies cited above. They continue teaching the way they were taught and pass their deficiencies on to their students. It is clear that this feedback system requires significant alteration. Teachers must be led to confront and answer questions such as those illustrated in this section. This must be done *explicitly* with all pre-service teachers, and most in-service teachers can benefit from retracing the logical structure of the introductory material even when they believe they "understand" it.

The encounter with electrostatic and magnetostatic forces provides a valuable opportunity for the kind of cycling back in altered context that research shows to be an effective aspect of instruction. The opportunity offered at this point is a re-encounter with Newton's Third Law after some time has elapsed since its use in mechanics. Those teachers who are inclined to believe that the issue has been settled through clear exposition and through the numerous exercises assigned in the earlier encounter would do well to try the following problem on students who have begun the study of electrostatics:

> Problem: Fig. 2 shows uniformly charged spheres firmly pinned to, and insulated from, frictionless pucks that ride on an air table. One sphere carries a charge of +2 units while the other sphere carries a charge of +6 units. The pucks, with the spheres they are carrying, are free to accelerate along the table.

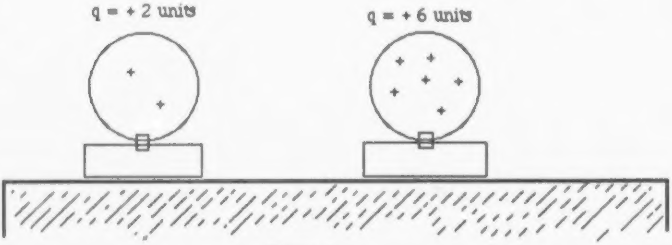

Figure 2

> Draw separate free-body force diagrams of each sphere and of each puck, showing all the forces acting on each of the four objects. When forces are equal, draw arrows of equal length; when the forces are not equal, show the larger forces with longer arrows to some reasonable scale.

When I gave this problem as a diagnostic test to a class of 40 second year university physics students who were beginning a course in modern physics after having completed a full year of introductory calculus-based physics, 65% of the group showed the electrical force acting on the left sphere to be three times as great as the electrical force acting on the right hand sphere, and 85% failed to show any horizontal force between the spheres and the pucks to which they were pinned, even though it was explicitly stated that the two systems were accelerating. Also, 60% of the class had something wrong with at least some of the vertical forces. (Most of these students would have given a correct verbal statement of Newton's Third Law if they were asked for it, but the ability to state the law does not mean that they think correctly about physical situations to which it applies.)

The reason for this very poor performance is that the students had made no use of the Third Law since their earlier exposure to it in the mechanics portion of the introductory course, and, furthermore, they had never had the opportunity to address qualitative questions such as the one illustrated here. We learn more from the *mistakes* we make than from the correct answers. It is important to give students the opportunity to make the kinds of mistakes they made on this problem. Only a few students repeat such mistakes on subsequent occasions.

7 Illustrations from Geometrical Optics

Goldberg and McDermott (1987) report an investigation of student conceptions regarding image formation by converging lenses. All the tasks involve questions concerning events on an optical bench that the interviewer and student viewed from the side. The apparatus on the bench included (1) an object consisting of the luminous horseshoe-shaped filament of an unfrosted light bulb; (2) a converging lens (diameter 7.5 cm; focal length 17 cm); and (3) a translucent screen. The inverted image of the filament was focussed on the screen, and the student viewed the screen from the side facing the lens.

In Task 1 Goldberg and McDermott framed the following question: "If the lens is removed, leaving the object and screen where they are, would anything change?" The majority of students who had not had instruction in geometrical optics (60%) responded that the image on the screen would become erect. About 40% of the students who had had instruction in geometrical optics gave the same response. On further investigation, Goldberg and McDermott found that the response in this task was, to some extent, confounded by the sharp nature of the object (the luminous filament); fewer students gave the incorrect response when an obviously diffuse light source (a frosted light bulb) was used as the object. The overall results, however, indicate that large numbers of students , even after conventional instruction, fail to recognize the absolute necessity of the lens for image formation. Even though they are fully aware that images of objects in the room do not form on the walls, they do not invoke such everyday awareness when viewing the apparatus on the optical bench.

In Task 2 the interviewer holds an opaque piece of cardboard above the lens but does not cover any part of the lens. The following question is then asked: ''Suppose I were to bring the cardboard down so as to cover the upper half of the lens, leaving the lower half uncovered, would anything change on the screen?'' Between 90 and 95% of preinstruction students predicted that half of the image would vanish, and between 55 and 75% of postinstruction students made the same prediction. Only a minority of the latter recognized that the entire image would remain and become less bright. In other words, even after instruction, only a minority of the students recognized that *any* portion of the lens is capable of forming the image.

The misapprehension arising in this context stems largely from the routine way in which students learn to draw ray diagrams. The texts show only the principal rays in order not to clutter up the diagrams. The students never draw anything *but* the principal rays. They never show the divergent bundle of rays emerging from every object point. They are never led to visualize what happens to the bundle that passes through any part of the lens regardless of where the principal rays happen to be. When they look at the diagram showing only the principal rays, they see the cardboard as cutting off the principal rays in the upper part of the diagram and conclude that half the image must disappear.

If one presents students with a problem sketched in such a way that the arrow representing the object is taller than the lens, many students find it impossible to draw the principal ray parallel to the principal axis because it never intersects the lens shown in the diagram. They fail to recognize that, once the plane of the lens is given, *all* the principal rays can be drawn regardless of whether all the principal rays actually pass through the lens. This reflects a gap in understanding closely related to that in the interview task.

In Task 3, starting with the image focussed on the screen,Goldberg and McDermott asked the question: "Suppose I were to move the screen toward the lens. Would anything change on the screen?" Among the postinstruction students only 35 to 40% recognized that the image would become fuzzy and disappear; the majority expected the image to persist, changing in size and perhaps becoming somewhat fuzzy. Goldberg and McDermott report the following:

> "Many of the remarks made by the students indicated that the function of the screen was widely misunderstood. Often they did not think of it as a diffuse reflector or transmitter that, when located at a particular position for a given object distance, makes it possible for an observer not looking along the axis of the lens to see the image. Instead they seemed to believe that an image can be seen on a screen no matter where it is placed along the axis. In some cases this claim seemed to be buttressed by a misinterpretation of the experience of watching someone else use a slide projector. The students may have remembered that, in order to make the image larger, the screen had to be moved farther from the projector. However, they did not recall that it was necessary simultaneously to refocus the projector by changing the object distance."

Many students fail to recognize the significance of the ray diagram in the sense that the intersection of the principal rays determines a *unique* image position and that an image is therefore not formed in any location other than the image plane. Furthermore, students have never been led to interpret the role of the screen in terms of diffuse reflection, that is, they have not been led to show each image point on the screen as a source of a divergent bundle of rays.

In Task 4 Goldberg and McDermott asked the student, while still looking at the image on the screen, if he or she would still be able to see the image from his or her present position (on the side of the screen facing the lens) if the screen were removed. Virtually all the students recognized that the screen was necessary for seeing the image from their given location, although several of the preinstruction students volunteered that they might be able to see the image on the wall several meters beyond the screen. The students were then asked whether they would be able to see the image if the screen were removed and they were free to take up any other position they wished. Goldberg and McDermott report:

> ''Many of the students, especially the preinstruction students, seemed to have difficulty understanding the question. Their remarks indicated that they could not conceive of an image existing in free space, independent of a surface. The majority of the students, both pre- and post-instruction, said either that they would not be able to see an image or that they might be able to see an image if they could place their eye at the screen position. Several of the students who gave the latter response seemed to think of their eye as simply replacing the screen.
>
> At this point in the interview, the investigator actually removed the screen and directed students to move about two meters beyond the initial screen position and to look along the axis toward the lens. With this guidance, almost all of the students were able to see the aerial image. Many appeared surprised that they were able to see anything.
>
> When the investigator asked for the location of the aerial image, only a very few students were able to state correctly that the image was located at the same position that the screen had been. The rest of the students gave a variety of answers. the preinstruction students, especially, tended to say that they thought the image was at or in the lens.''

It is my own experience that, if one asks students to give an overall description in their own words of what happens to the light which emanates from the object, is intercepted by the lens, and ends up forming the image on the screen, a substantial number tell a story that effectively boils down to something like "The image travels from the object to the lens; in the lens it is turned upside down; then it travels to the screen.''

Again in my own experience, I have found it helpful to require students, when drawing ray diagrams on homework and tests, to write out full verbal descriptions of how each principal ray is drawn (this in connection with both converging and diverging lenses.) Many of the initial versions tend to be gibberish, indicating that the students have not registered the ideas involved and are just following memorized diagrams or procedures without making explicit connection to operational definitions of principal foci and rays. Only after the verbal description has been written out correctly and clearly at least once, and subsequently applied to problems that involve image formation by two lenses in sequence, can this writing requirement be relaxed.

Another very useful technique for tests and homework is to help the students reverse the common direction of reasoning. Instead of asking for the image location given an object position, one can give the image and lens locations and ask where the object must have been. (Reversing the sequence of reasoning is a powerful general tool in enhancing learning and in advancing mastery of associated concepts and lines of reasoning.)

Generally speaking, very little genuine understanding of images and image formation is registered under homework that consists principally of numerical calculations using either the Gausssian or Newtonian lens equations. This remark is not meant to advocate elimination of the numerical work. The latter is necessary and important, but it needs to be coupled directly, preferably in the same problems, to questions of the kind used by Goldberg and McDermott, i.e., phenomenological questions that are shown to be far more difficult to address and assimilate than are the numerical routines.

It is clear that homework assignments, tests, and *laboratory work* should contain questions of the kind illustrated in the preceding discussion. Many variations of such questions could and should be devised. At present, one cannot avoid the conclusion that most conventional instructional routines fail to lead many students to the kind of understanding we would like them to achieve.

8. Summary Remarks and Implications for Teacher Training

The implications for teacher training of the researches summarized in the preceding sections are manifold and serious. Since most teachers are taught by means of existing curricular materials in the conventional manner, many of them emerge from this training with the same gaps and misconceptions revealed in the researches. Although the real, long term remedy for this problem resides in alteration of the curricular materials and instructional techniques in general, as well as in the reduction of the volume and pace at which subject matter is forced on students in our introductory courses, it will probably be quite a long time before such reforms penetrate the entire educational structure. While the efforts at long term reform are under way, it is necessary to reach the teacher population directly in their preservice education, in practicum experience, and in inservice workshops. There are several levels of insight that must be cultivated in such endeavors:

(1) Teachers need to be led to review and re-examine, from a deeper and more mature perspective than that conveyed in most introductory physics courses, subject matter with which they believe they are familiar. They must be led to track down the "how do we know ... ? why do we believe ... ? what is the evidence for ... ?" questions that lie behind the concepts, laws, and models that they will be teaching. They must have sophisticated control of the processes and sequences of operational definition of all the concepts that are to be developed. They must be able to think phenomenologically in all areas of the subject matter and not just be able to solve the numerical end-of-chapter problems. They must be adept at directing students to everyday phenomena that are related to the abstract schemes being developed in the classroom.

(2) Teachers must be made aware of research literature such as that described in this paper. Such awareness can be cultivated in the context of retracing the conceptual structures as advocated in the preceding paragraph.

(3) Through awareness of the research results and procedures, teachers should be helped to cultivate the capacity to observe their own students: to learn how to ask searching questions; to listen to and interpret student response without destroying the insights to be gained by prematurely stepping in and answering questions as soon as the students exhibit difficulties and misconceptions.

(4) Teachers must learn how to supplement the questions and problems in the conventional textbooks so as to direct students toward filling the gaps and rectifying the misconceptions revealed in the researches. (It has been indicated repeatedly in this paper that many of the questions and techniques used in the researches are directly applicable and transferrable to this aspect of instruction, but competent teachers must be able to invent and use additional, similar questions of their own.)

(5) Teachers should become keenly aware of the need of continually spiralling back and applying earlier concepts, repeatedly, in new and increasingly rich context in all those areas in which research shows that students exhibit difficulty with concept formation and lines of reasoning. (In such context, teachers should be made explicitly

aware of the enhancement afforded by providing opportunities for *reversal* of the direction of the line of reasoning wherever possible.)

(6) Since the real intellectual goals of any course are set not in the textbook, or in the public description of the course, or in the lecture presentation of the subject matter but in the *testing* on which grading and evaluation are based, teachers must be helped to develop the capacity to generate test questions that direct the students to full grasp and understanding rather than, as is presently largely the case, to superficial problem solving that is not accompanied by understanding. Questions of the kind that have been used in the researches to establish the actual levels of student understanding clearly illustrate what needs to be added to existing modes of instruction.

BIBLIOGRAPHY

ARONS, A. B. (1976), ''Cultivating the Capacity for Formal Reasoning,'' *Am. J. Phys.* **44**, 834.

ARONS, A. B. (1982), ''Phenomenology and Logical Reasoning in Introductory Physics Courses,'' *Am. J. Phys.* **50**, 13.

ARONS, A. B. (1983), ''Student Patterns of Thinking and Reasoning, Part One,'' *The Physics Teacher* **21**, 576.

ARONS, A. B. (1990), *A Guide to Introductory Physics Teaching* (John Wiley & Sons, New York).

CHAMPAGNE, A. B., KLOPFER, L. E., and ANDERSON, J. H. (1980), ''Factors Influencing the Learning of Classical Mechanics,'' *Am. J. Phys.* **48**, 1074.

CHIAPPETTA, E. L. (1976), ''A Review of Piagetian Studies Relevant to Science Instruction at the Secondary and College Level,'' *Sci. Ed.* **60**, 253.

CLEMENT, J. (1982), ''Students' Preconceptions in Introductory Mechanics,'' *Am. J. Phys.*
50, 66.

COHEN, R., EYLON, B., and GANIEL, U. (1983), ''Potential Difference and Current in Simple Electric Circuits: A Study of Students' Concepts,'' *Am. J. Phys.* **51**, 407.

DI SESSA, A. (1982), ''Unlearning Aristotelian Physics: A Study of Knowledge-Based Learning,'' *Cog. Sci.* **6**, 37.

FREDETTE, M. H. and CLEMENT, J. (1981), ''Student Misconceptions of an Electric Circuit: What Do They Mean?,'' *J. Coll. Sci. Teach.* **10**, 280.

GOLDBERG, F. M. and MCDERMOTT, L. C. (1987), "An Investigation of Student Understanding of the Real Image Formed by a Converging Lens or Concave Mirror," *Am. J. Phys.* **55**, 108.

GUNSTONE, R. F., CHAMPAGNE, A. B., and KLOPFER, L. E. (1981), "Instruction for Understanding: A Case Study," *Australian Sci. Teachers Jour.* **27**, 27.

GUNSTONE, R. F., and WHITE, R. (1981) "Understanding Gravity," *Sci. Ed.* **65**, 291.

HALLOUN, I. A. and HESTENES, D. (1985), "The Initial State of College Physics Students," *Am J. Phys.* **53**, 1043; also "Common Sense Concepts About Motion," *Am. J. Phys.* **53**, 1056.

KARPLUS, R., KARPLUS, E., FORMISANO, M., and PAULSEN, A-C. (1979), "Proportional Reasoning and Control of Variables in Seven Countries," in *Cognitive Process Instruction*, LOCHHEAD, J., and CLEMENT, J., eds. (Franklin Institute Press, Philadelphia).

MCDERMOTT, L. C. (1984), "Research on Conceptual Understanding in Mechanics," *Physics Today* **37**, 24.

MCDERMOTT, L. C., ROSENQUIST, M. L., and VAN ZEE, E. H. (1987), "Student Difficulties in Connecting Graphs and Physics: Examples from Kinematics," *Am. J. Phys.* **55**, 503.

MCKINNON, J. W., and RENNER, J. W. (1971), "Are Colleges Concerned with Intellectual Development?" *Am. J. Phys.* **39**, 1047.

MCKLOSKEY, M., CAMARAZZA, A., and GREEN, B. (1980), "Curvilinear Motion in the Absence of External Forces," *Science* **210**, 1139.

MINSTRELL, J. (1982), "Explaining the 'At Rest' Condition of an Object," *The Physics Teacher* **20**, 10.

PETERS, P. C. (1986), "Even Honors Students Have Conceptual Difficulties with Physics," *Am. J. Phys.* **50**, 501.

STEVENSON, H. W., SHIN-YING, LEE, and STIGLER, J. W. (1986), "Mathematics Achievement of Chinese, Japanese, and American Children," *Science* **231**, 693.

TROWBRIDGE, D. E., and MCDERMOTT, L. C. (1980), "Investigation of Student Understanding of the Concept of Velocity in One Dimension," *Am. J. Phys.* **48**, 1020.

TROWBRIDGE, D. E., and MCDERMOTT, L. C. (1981), "Investigation of Student Understanding of the Concept of Acceleration in One Dimension," *Am. J. Phys.* **49**, 242.

VIENNOT, L. (1979), "Le Raisonnement Spontane en Dynamique Elementaire," *Eur. J. Sci. Ed.* **1**, 205.

WHITE, B. (1983), "Sources of Difficulty in Understanding Newtonian Dynamics," *Cog. Sci.* **7**, 41.

MODERN PHYSICS PIECES 0F INFORMATION TEACHING PROCESS

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An important factor in educating–tuiting process in natural sciences and mathematics is the communication, i. e. an approach which mediates understanding and comprehending the results of contemporary science. It is necessary to make the scientific results correctly clear to pupils so that they comprehend them in their real sense and significance.

The physics didactics as the border discipline is characteristic by its integrating development form in which partial disciplines are integrated within the frames of newly arisen branch didactics. The communication appears in it as one of the integration factors. (We then speak abaut integration–communicating conception of branch didactics.) Scientific results pass several times through didactic transformation before they get to a pupil. The choice and arrangement of the subject matter should – according the didactic communication theory – procede not only the textbooks creation but also instructional plans and programmes.

It is necessary to search and find a suitable mode and possibilities how to insert the modern physics knowledge into the lessons in the most effective way. It is not possible to widen more and more the surcharged (contemporary) physics programme, it is not even possible to fail by pen scraping "the only too traditional" parts of lessons. What could be then changed? The differentiation in secondary schools education shows to be necessary as well as the more tight contact of pupils interested in physics directly with the physicists themselves /1/.

Within the frames of basic research state plan in physics didactics in Czechoslovakia in years 1986 – 90 the problems of madernization of basic schools physics teaching from the point of view of its content was solved as well as the project of physics teaching perspective conception on special type of Czechoslovak secondary school called "Gymnasium" (providing the most general education) was worked out and a part of experts´ solving capacity was devoted to the education of physically talented pupils.

In coordination of physics didacticists, physicists and physics teachers a collection of laboratory excercises (in print) was created which enables to apply modern physical knowledge in the lessons and ofrces the pupil to separately work with the text and to manage with experimantal problems, too. Some quite new tasks, e. g. the Monte Carlo method and the speed–up were inserted into this collection, the basic characteristic of its arrangement is, however, its method of working: the pupils acts separately in solving the tasks, the teacher only as the consultant. The collection will be used above all for deeper preparation of pupils in physics within the frame of specialized groups.

The preparation of Gymnasiums´ physics teaching perspective conception came out besides working out the theoretic part also from a concrete experimental research. New original lessons were made out - the so called "sonds" – they refer those parts of subject matter which should be newly didactically conceived or which refer to modern results of physics – e.g. Holography, Plasma, Liquid Crystals, Solid State Band Theory. We can expect that the research conclusions can influence not only the new physics programme creation but Gymnasiums in Czechoslovakia assumes a more expressive differentiation in physics teaching /2/.

The out–school special physics activity of pupils is also very significant, it is connected tightly with school programme. It includes in Czechoslovakia not only a traditional Physical Olympiade but also a specific Secondary schools Special Activity (i.e. solving separate special tasks by pupils lead by consultants) as well as the Young Physicists´ Tournament (solving and discussing non–traditional physical problems by pupils teams) which now developes on international level.

Pupils motivation for physical study originates only from the physics itself. It is necessary not to "conceal" before the pupils the novelties of physical research, but on the contrary to help them to look into the "physical kitchen" .

Literature:

/1/ Kluiber, Z. – Loncarova, J.: Achievements of modern physics in perspective conception of physical education. In: Proceedings of international conference on teaching modern physics – condensed matter; Editors: K. Luchner and collective; World scientific, Singapore 1989,p. 418.

/2/ Kluiber, Z. and coll.: Perspective didactic system of physics (in (Czech). Paper of physical component of the partial task of Czechoslovak basic research state plan IX–10–2/2. Institute of Physics, Czechoslovak Academy of Science, Prague 1990, p. 108.

THE INTEGRATION 0F MATHEMATIC AND NATURAL-SCIETIFIC EDUCATION IN CZECHOSLOVAKIA

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The basic research of physical education in Czechoslovakia in years 1986 - 90 was aimed to the concretization of mathematic-natural scientific education, to working out common entrance text, integrated course, as the base of all natural sciences subject matter in secondary schools from which would emanate and to which would link individual natural-scientific subjects, to working out intersubject connections and to the development of work with physically talented pupils. In solution of the basic research 40 experts from Czechoslovak Academy of Sciences, universities faculties, Ministry of Schools, Youth and Sports took part; they devoted approximately 17 thousand hours per annum to this problem.

The system analyse of the subject matter (carried out in years 1981 - 85) proved that the structure of physics subject matter has a basic significance for the preparation of natural-scientific perspective conception. Therefore the experts started to work out a project of physics teaching perspective conception on special type of secondary schools (providing the most general education called in Czechoslovakia "Gymnasium" which become the initial material for research in coordinated mathematic-natural scientific education in years 1986 - 90. This material was widely scrutinized and the results of this investigation have supported the suggested structure of subject matter. This proposal concretizes and works out the sooner prepared frame project of the course "Structure and Development of Mass". The course is based on integrating tendencies in natural sciences and coherent system of mass structure. according to this model above all the unifying elements and the structure of mass development should be stressed and the homogeneous natural-scientific Picture of the world should be built in physics teaching./1/, This aspect shows to be an important criterium for choice and apprehension of subject matter. A brief content of main chapters in individual Gymnasium´s classes (there is of course a sure variability of themes) is following:

1. the composition of substances from particles, atomic nucleus, atomic cover, atoms´ connections in molecules (the explination of subject matter was carried through also quantitatively and some necessary knowledge from other areas of physics, e.g. mechanics, optics etc. were used);
2. mechanical movement of free particles and bodies, thermodynamics;
3. solid state physics, electromagnetic induction;
4. plasma, light, stars, cosmos; summary of secondary school physics knowledge.

So this apprehension of physics teaching expressively changes the untill now traditional arrangement of thematic wholes of secondary schools subject matter. Therefore the attention in research work was and is still paid above all to important points of perspective conception of physics teaching including the whole system of 1st class subject matter, then some parts from solid state physics, optics, plasma, thermodynamics etc.

The detailed methodc working out of the subject matter would not be surely simple. However, it could become a certain way to solving the problems of "Gymnasiums" physics teaching: the pupils can come to know about new aspects of physics already in the 1 st class, the overfilling the lessons is thus forestalled. Pupils should then comprehend what is the real aim and content of the modern physics so that they could see under the term physics not only tecnical aplications but above all its knowledge function.

The above said model of physics teaching conception can influence the preparation af optimal physics teaching conception in coming up period, respectively to become also the alternative course of Gymnasiums physics lessons /2/.

Literature:

/1/ Kluiber, Z.: Solid state physics in perspective conception of physics teaching in Czechoslovakia. In: Proceedings of international conference on teacning modern physics –

condensed matter; Editors: K. Luchner and collective; World scientific, Singapore 1989, p. 417.

/2/ Kluiber, Z. and coll.: Perspective didactic system of physics. (in (Czech). Paper of physical component of the partial task of Czechoslovak basic research state plan IX– 10–2/ 2. Institute of Physics, Czechoslovak Academy of Sciences, Prague 1990, p. 108.

PROBLEMS OF TEACHING PHYSICS IN ESTONIAN UNIVERSITIES

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In Estonian higher schools there are two kind of problems concerning physics: first is connected with finding criteria for good teaching and the second is connected with physics for engineers. In the following I mainly try to explain how the latter problem crop up and present the ideas to improve the education for engineers.

The social and political developments in our country give to the revaluation of education too. In Estonia the problems of reorganisation of education in all levels are under serious investigation, but the proposed projects are not yet satisfactory concerning especially physics and other fundamental subjects. The main reason lies in the fact that fifty years we have been the part of Soviet system which has now reached its potential minimum. The educational system of Estonian Republics was demolished in forties and now we out a new educational system which is suited for our society. It is impossible to copy some western systems because one must take into account the socia and mental level of our society.

In the Soviet system of education which we now try to demolish there are some points which deserve some attention. In fifties the technical education in polytechnic institutes was on the needed level and there were elitary institutes, like Moscow Physico-Technical Institute, where the technical education was in the top level. The higher technical education was based on a solid foundation of fundamental subjects - mathematics and physics. The courses of mathematics and physics for engineers constitute 1/4 to 1/3 from total auditorium time. Due to the offensive of marxist subjects the role of basical courses has been stedily reduced and now in polytechnical institutes the role of basical subjects, especially physics, has been reduced below the minimun from which the normal technical education is possible. The given technical education lies somewhere between the technician and engineer. The same processes took place also in Tallinn Polytechnic Institute - now reached its old name - Tallinn Technical University. It should be supposed that now when the marxist subjects are excluded and changed to humanitary subjects the role of physics is restored, but it is not so. In following the general structure of basical subjects for higher technical education is given, which by our meaning may be useful in other countries too. In order to have some reference system I give our auditorium time shedule: we work 17 weeks in semester and now it is accepted that students work 26 hours in week. The five years study gives totally 260 week-hours.

In Tallinn Technical University the minimum for physics is 8 week-hours and maximum - 14 week-hours (1O for general course and 4 for special course). Therefore the maximum course gives two semesters 5 hours in week to pass the whole physocs from mechanics to quantum physics. Ten years ago the maximum for general physics was 16 week-hours distributed to three semesters.

Next we give the time shedule which must be used in technical universities. The main principle is that the basical courses of physics and mathematics must constitute 1/4 to 1/3 from total auditiorium time limit. Mathematics and physics (general + theoretical course) are distributed 50-50.

The ordinary technical education must have the basical education (independently from speciality) 65 week-hours: 33 - mathematics, 23 - general physics and 9 -theoretical physics. The higher level (needed for postgraduate studies) must give 86 week-hours: 43 - mathematics, 30 - physics and 13 - theoretical physics.

It goes without saying that the following special study must be based on the foundation lied by basical courses of mathematics and physics. In the present time it is unfortunately not so. So, we have a long way to go to reach the normal system of education which is better suited with our needs and possibilities. A good education on any practical lines is impossible without a solid fundamental basis.

ALTERNATIVE IDEAS IN MECHANICS: WHERE CAN THEY COME FROM?

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INTRODUCTION

Since the late seventies there has been an ever increasing interest for the study of alternative ideas in science topics. Mechanics soon deserved researchers' special attention and is surely the topic on which the largest number of studies has been carried out. Almost all these studies concentrated on the identification of students' alternative ideas, leading to the conclusion that they do exist and resist to instruction.

Although Viennot, in 1979, had already pointed out that the set of spontaneous, intuitive or natural explanations held by students about mechanics "could not only be the result of ignorance or deformation of formal knowledge" (Viennot, 1979), very little progress has been made towards the identification of the causes of students' alternative ideas in mechanics. However, a few authors have tried to find an answer to the questions: a) Why do people construct some personal concepts? and b) Why do those concepts differ from and resist to what people are taught?

According to P. Hewson (1985), people' ideas or concepts exist as a result of a process of natural selection undertaken by the individuals' intelectual environment which favours the development of some concepts and inhibits the development of others. The individuals' construction of ideas and concepts about the natural world requires a fit between the subjective purpose of knowing and the objective context. When doing so, individuals often look at something as if it were something else, seeking for analogies which help them to achieve that fit (Guidoni,1985). The natural analogical reasoning undertaken in this process is based on individuals' schematic prototypes or duplicating schemes which often lack in fit and/or are handled by strategies not enough developed. In any of these cases, natural analogical reasoning is likely to lead to natural thinking and alternative ideas. The existence of similar basic ideas in different individuals is due to the fact that their way of processing ideas is driven by the invariance of external phenomena and by stable cultural patterns. Therefore, M. Hewson (1985) calls our attention to the fact that the origin of alternative ideas has to be viewed in the context of people's intellectual environment. According to P. Hewson (1985), it includes individual and social beliefs, language, accepted theories, observed facts and events. It has also been argued that actions on the world, social interaction (Ogborn, 1985), learners' previous mental schemes (Driver, 1988), differences between accepted ideas and ideas presented by some teachers and textbooks, teachers' unwareness of students' alternative ideas and the way science content is sequenced, organized and "presented" to the students (Martins, 1989) can also contribute to alternative ideas.

Despite the fact that multiple sources of alternative ideas have been pointed out in the literature, the work done on this topic consists mainly of theoretical reflections based on the results of studies aiming to identify students' explanations about mechanics phenomena.

This paper aims to be the authors' first attempt to identify some causes of secondary school students' alternative ideas in mechanics. The research reported here shows the first results obtained within a larger project focusing on the origin of students' ideas in mechanics.

METHODOLOGY

Taking into account the diversity of origins of alternative ideas referred to in the literature and in order to get as much information as possible, data were collected from three sources: students, physics teachers and textbooks.

To investigate where students get their alternative ideas from, eight secondary school students (four nineth graders, who had not studied mechanics, and four tenth graders, who had studied this topic for the first time) were interviewed by one of the authors, about four problematic situations (Appendix 1). These situations can be interpreted by the use of mechanics, although they are often explained by students based on their own ideas (Sequeira and Leite 1989; Sequeira, Leite and Duarte, 1989). The sequence of the interview is basically the following: describe what happens; explain why; how do you know that / where did you get that idea from.

To investigate whether physics teachers hold alternative ideas on mechanics, a questionnaire was prepared by the authors and responded by 17 teachers. This questionnaire contains the four problems referred to above and some possible answers to each question of the problems, including the correct answer and the most frequent alternative answers among students, before and after instruction on 10th grade mechanics. Teachers were asked to circle the correct answer to each question.

Finally, a brief analysis of the chapter of mechanics in the four most important Portuguese 10th grade physics textbooks was carried out in order to evaluate the extent to which textbook writers take students' ideas into account and promote their conceptual change.

DISCUSSION OF RESULTS

The data collected from the different sources considered in this study will be analised separately: students, teachers and textbooks.

A - Students

The alternative ideas expressed by the interviewees participating in this study are similar to the ideas identified by the authors in some previous studies (e.g. Sequeira and Leite, 1989; Sequeira, Leite and Duarte, 1989).The number of interviews is very low and therefore no statistics will be performed. Rather, interviewees' answers will be used in a descriptive way in order to get some insight on possible causes of students' alternative ideas.

The main alternative ideas expressed by the students can be summarized as follows:

> 'Objects need a support, whatever it is, otherwise they cannot stand and they fall. The falling velocity of the objects depends on their weight so that the heavier object falls faster, when fall occurs in the air. In the vacuum, objects do not fall because there is either no atmosphere or no gravity. When objects are moving, there has to be a force or a net force acting in the direction of motion. If, at a given instant, this force stops and another force is applied to the moving object, the direction of motion changes to the direction of the applied force. The force (or the net force) acting on a moving object is proportional to its velocity. If the force stops, the object either stops immediatly or continues moving for a while with slowing down motion or it falls.'

Let us now try to identify the possible causes for the alternative ideas expressed by the students.

1 - *Objects need a support, otherwise they would fall.*

Students are used to see objects either on a support (such as a string, the ground, another object, etc.) or falling (when the support is taken away). Therefore, they cannot accept the idea of a spaceship moving in deep space without a support which can be either an engine on or an upwards force. This can be illustrated by the following quotations taken from the interviews.

> "... If the spaceship has no force it falls; There has to be something holding it up. I am sure... There has to be an upwards force to keep the spaceship up there... It needs the engine N on [to move from left to right] and... an upwards force to keep it up." (10th grader);

> "[When the only engine on is turned off, the spaceship] falls... the spaceship cannot stand... it cannot stay there. When a person feels weak he/she faints because he/she is not strong enough to stand up The spaceship would stop only after falling." (10th grader).

2 - *The heavier an object is the faster it falls, in the air.*

The interviewees were asked to compare the falling time of two equal size spheres, one made out of iron and the other made out of wood, when they are released from the same level, in the air. They all stated that the "iron sphere would fall faster because it is heavier than the wood sphere". They argued they knew it from their everyday experience with "heavy" and "light" objects and even described some experiences which they had done or could do in order to corroborate their previous answer. Some examples of experiences described by the students are given below.

> "[I have done an experiment] with stones… a bigger stone and a smaller stone; the bigger stone falled faster than the smaller stone." [9th grader];
>
> "I have done [an experiment] with a piece of chalk and a stone… the stone reached the ground sooner because it is heavier." (10th grader).

The air resistance is always there and students do not perceive its influence on the falling time. They only perceive the influence of what may or may not be there and therefore base they answers on it. Weight is a characteristic of the objects which students easily perceive as changing from one object to the other and that seems very appealing to them.

3 - *In vacuum, objects do not fall; they float.*

Students have watched TV programs and science fiction films in which they could see astronauts floating either in the moon or in deep space. They know that in the moon, like in outer space, there is no atmosphere. They, therefore, deduced (incorrectly) that the non existence of atmosphere was the cause of floating in space and answered to the question about the spheres in the vacuum tube based on the characteristic it has in common with outer space, that is, absence of atmosphere. An illustrative example is given below.

> "… As there is no air, they would stay in the same place; they would not fall… In outer space there is no air and people float [I have watched it] on TV." (9th grader).

On the other hand, some students know that the weight of an object is smaller on the moon than it is on earth. Besides, they can watch on TV, people floating on the moon's surface. Then, they conclude that in vacuum there is no weight/gravity and, therefore, they state that objects do not fall inside a vacuum tube.

4 - *Motion requires a force in the same direction.*

Students live in a world with friction where they have to exert a force on any object they want to keep moving in a well defined direction or with a certain velocity. Therefore, they invent forces to explain slowing down motion consistently with their everyday experience that motion requires a force in the same direction. One student put it this way:

> "… the coin goes up… due to the fact that the force I gave to it is bigger than… the force of gravity; otherwise, the coin would not go up" (10th grader).

This belief is so deeply rooted in students' minds that, even after studying Newton's first law, students hardly accept objects moving in a frictionless space, without any applied force. This statement can be illustrated by the following quotation from students' interviews:

> "The spaceship would not move if there was no engine on. The engine N is on... because it is behind the spaceship... It exerts a force on the spaceship so that it can move." (10th grader).

> "Engine N is on... there has to be something that makes spaceship move like that." (10th grader).

As it had already been found in a previous study (Sequeira and Leite, 1989a), sudents feel a need for a cause to explain every phenomena. Maybe, because of that, they hardly use the law of inertia which does not include any causal relationship.

5 - *Force is proportional to velocity.*

Almost all interviewees stated that the speed of the spaceship moving in deep space (no friction, no gravity) would be constant if the functioning power of the engine is constant, it would increase with the the power of the engine and would decrease with it. Some students stated that they knew it from their

> "... experience with cars... If we accelerate more and more, the car goes faster and faster; if we accelerate less and less, it goes slower and slower; [if acceleration is constant, the speed] will be constant" (10th grader).

6 - *The direction of motion changes to the direction of the applied force.*

Some students stated that the spaceship moving horizontally (they say, with engine N on) would change instantaneously to the vertical, when engine N is switched off and engine K is switched on. These students do not consider the inicial velocity of the spaceship and base their answers only on the position of engine K.

However, other students acknowledge the idea that the direction of motion does not change instantaneously to the direction of the applied force/engine on. These students base their answers on their everyday experience with cars changing their direction of movement, as illustrated below.

> "[The spaceship]... would change its trajectory... and it would go down... I am... comparing it... with a car. The car does not move immediatly from one direction to the other." (10th grader).

But these students believe the change of direction would occur very rapidly so that, after a short while, the spaceship would be moving in "the direction of the engine on".

7 - *If the force stops, the objects either stop immediatly or continue moving for a while, with slowing down motion, or they fall.*

When the force acting on a moving object stops (engine turned off or force used up), the object stops immediatly "because there is no longer a force acting in the direction of motion". Other students believe the object would fall due to the non-existence of a "support".

However, some students accept the idea that the spaceship can move after the engine is turned off but they refuse the idea that it continues moving with the same velocity after the engine is turned off. They put it as follows:

> "The spaceship loses the force but it continues moving downwards... At first, it moves faster but after a while it moves slower.[At the beginning] it still has the force the engine has given to it. [Later] the force will vanish."(10th grader].

This kind of explanation seems to be based on students' experience with cars, as explained by one of the interviewees:

> "It is not because one switches off the engine of a car that it does not move... The spaceship would continue moving downwards... until it reaches the ground.When this happens, it stops... As the spaceship gets nearer the ground, its velocity would decrease" (10th grader).

B - Teachers

When physics teachers responded to the questionnaire with the same problems of the interview conducted with the students, some of them gave alternative answers, as shown in table 1.

TABLE 1 - Physics teachers' performance by problem.

(N = 17)

Problem	Correct answer		Alternative answer		Cannnot answer	
	f	%	f	%	f	%
Spaceship	14	82	2	12	1	6
Coin toss	11	65	5	29	1	6
Two spheres:						
- air	6	35	11	65	0	0
- vacuum	17	100	0	0	0	0
Book on table	17	100	0	0	0	0

Teachers' alternative answers include the following ideas: a) the heaviest of two equal size spheres falls faster, in the air, because it is the heaviest (Two spheres problem); b) when a coin is tossed up, it acquires a decreasing upwards force (Coin toss problem); c) the spaceship moving in deep space with constant velocity requires an engine on or a net action of several engines in the direction of motion (spaceship problem); d) The direction of a moving object changes abruptly to a different and permanent direction, when a force is applied to the object (Spaceship problem).

In a previous study, 16 physics teachers were asked to answer to a different version of the spaceship and the coin toss problems, under examination conditions. Only 25% of the teachers were able to answer correctly to the spaceship problem and 50% to the coin toss problem. The remaining teachers expressed alternative ideas similar to those usually expressed by students (Sequeira and Leite, 1989).

The results presented here corroborate the statement that some alternative ideas are very resistent to science teaching and lead us to question ourselves about the effectiveness of physics teaching. We cannot say, in the context of this study, that teachers who hold alternative ideas would present them to their students. If they were going to use this problems in their classes they would hopefully think about them and teach them according to newtonian mechanics. However, teachers can be faced with students' alternative ideas which are similar to the ideas they themselves hold unconsciously. In this case, we think that it would be very difficult for the teachers to perceive that the ideas held by their students need to be changed and therefore they would not promote students' conceptual change. Another possibility would be that students undergo a conceptual change of their own ideas to the teachers' alternative ideas.

C - *Textbooks*

A brief analysis of the chapter of mechanics in four 10th grade physics textbooks (Silva and Valadares, 1985; Almeida and Silva, 1984; Sá, 1987; Pereira et all, 1983), leads us to conclude that textbook writers do not take into account students' alternative ideas about mechanics concepts and principles. Athough several cognitive science studies have shown that very few concepts (if any) included in 10th grade mechanics are really new to the students, the textbook authors state objectives for the students to master concepts and principles as if they were all new to 10th graders entering mechanics classes. It seems that the authors of the textbooks are more concerned with the amount of "new" concepts the students are supposed to learn (probably, by rote learning) than with the conceptual change of the students' prior ideas into meaningful accepted concepts.

The contents included in mechanics are basically the same (following the syllabus) and in general there is little integration, if some, among the different contents, namelly between kinematics and dynamics. Silva and Valadares (1985) try to develop some concepts further than the other authors do and present them in a slightly different sequence which seems more promising in terms of giving students a better understanding of some concepts. Two of the textbooks (Sá, 1987; Almeida and Silva, 1984) introduce too many concepts to describe motion, being some of them unnecessary and even confusing to students. In fact, they use, for example, the concepts of average velocity and average acceleration as being scalar quantities, related to the change of position measured over the trajectory, instead of the accepted concepts of average velocity and average acceleration as vectorial quantities, related to the change of position in a given frame of reference. The accepted concepts of average velocity and average acceleration are labeled by these textbook authors as vector average velocity and vector average acceleration. It should be noticed that, in these textbooks, the words average velocity and average acceleration do not mean the magnitude of the vector average velocity and the vector average acceleration. We are affraid of the possibility of sudents not perceiving these differences of meanings and getting even more alternative ideas than they already have.

In what concerns the presentation of the content, none of the textbooks takes into account the existence of certain alternative ideas among students even when they have a good opportunity to do so without any extra effort. Take, for example, the case of a textbook (Pereira et all, 1983) which describes and suggests students to perform an experiment which would enable them to establish a relationship between the force acting upon a body and the rate of change of velocity. Instead of testing the idea commonly accepted among students that $\vec{F}$ is proportional to $\vec{v}$, the authors assume, from the very beginning, that $\vec{F}$ is proportional to $\Delta\vec{v}$. This procedure does not promote students' conceptual conflict and diminishes the interest of the experiment, as the relationship is to be confirmed and not "discovered".

It is very stricking to find in the textbooks some statements (sometimes in bold) and concept definitions which either are scientifically incorrect or can lead students to reinforce their own ideas. The following paragraphs, which can be found in one of the textbooks, corroborate the previous statement.

> "If there is no force acting on a body, its velocity remains constant; therefore, the body moves on a straight line with uniform motion.
> In summary, we state the first principle of dynamics, that is, the inertia principle, as follows:
> To a nule force it corresponds a nule acceleration. " (Almeida and Silva, 1984, p.100).

In fact, there can be forces acting on a body and its velocity can remain constant. The condition is that the forces are balanced.

Another textbook stated:

> "The weight of a body is, then, the force responsible for the acceleration in free fall, g, that we can observe." (Sa, 1987, p. 141)

The first part of this statement is what students (and even some physics teachers) say and deeply believe in. We believe that one should be very careful when explaining free fall and fully interpret it both in terms of forces (including air resistance) and changes of velocity.

One more example concerns the definition of weight given in one of the textbooks. It is as follows:

> "Weight is the net force of of the forces exerted by the earth upon the bodies" (Almeida and Silva,1984, p.104).

Although the authors of this definition recognize (in a footnote) that it is an approximate definition of weight, we think that there is a need to distinguish between weight and gravity. We believe that we could give students a more accurate definition of weight, as Silva and Valadares (1985) do without making the concept more difficult for them to understand. In fact, it seems that weight as the net force applied to an object, when it is on a support, is not only more correct but, at the same time, more in agreement with their experience. Besides, we would like to argue for the need of speaking about interaction between the earth and the object instead of speaking about atraction of the earth. In doing so, we would certainly contribute to decreasing the number of students feeling like the interviewee who stated:

> "It does not make sense to me... Each object has its weight. If it was the earth that atracts the objects, than it should atract all with the same weight." (9th grader).

CONCLUSIONS AND IMPLICATIONS

The results of this study seem to indicate that:

a) Students themselves can construct and/or find ways of reinforcing their alternative ideas about mechanics phenomena. When doing so, they use information from their everyday experience (with cars, falling objects, astronauts, etc.), from the mass media (namely, from TV programs, science fiction films and books) and from their contacts with relatives, peers and teachers. Students' alternative ideas are often a result of a process in which students interpret different facts and phenomena as if they were analogous because they do not perceive the characteristics that distinguish them. This process seems to be also influenced by students' beliefs which sometimes prevent them from acquiring the accepted ideas.

b) Teachers may contribute to the persistence of their students' alternative ideas or even to the construction of new alternative ideas if they themselves hold these ideas without perceiving them. In this case, teachers are not aware of the need to change students' alternative ideas because they themselves believe in the same ideas.

c) The authors of the textbooks in this study do not take students' alternative ideas into account and some textbooks can even contribute to the reinforcement or the construction of alternative ideas.

Therefore, it seems necessary to take into account the analogies used by the students, in order to help them to discover the fundamental characteristics and the order that lie beneath the appearance of physical phenomena, so that effective learning can occur. It seems also necessary to make teachers aware of the problematic of alternative ideas so that they become conscious of the fact that a) they themselves can hold alternative ideas and b) their students' ideas are resistant to science teaching and require teaching strategies specially devised to promote conceptual change. Besides, physics textbooks need to be revised both in what concerns the underlying theory of learning and the way some physics concepts are defined, sequenced and organized. However, deeper research is needed to identify the causes of students' alternative ideas, so that we can acquire the background information needed to devise appropriate teaching strategies to change students' alternative ideas about mechanics concepts.

REFERENCES

Almeida, C. & Silva, M. (1984). *Física - 10º ano de escolaridade*. Porto: Porto Editora.

Driver, R. (1988). Restructuring the science curriculum: Some implications of studies on learning for curriculum development. *In* Sequeira, M., Leite, L. & Freitas, M. (Eds). *Actas do 1º Encontro Sobre Educação em Ciências*. Braga: Universidade do Minho.

Guidoni, P. (1985). On natural thinking. *European Journal of Science Education*, 7(2), 133-140.

Hewson, M. (1985). The role of intellectual environment in the origin of conceptions: A exploratory study. *In* West & Pines (Eds). *Cognitive Structure and Conceptual Change*. Chicago: Academic Press.

Hewson, P. (1985). Epistemological commitements in the learning of science: Examples from dynamics. *European Journal of Science Education*, 7(2), 163-172.

Martins, M. (1989). *A energia nas reacções químicas: Modelos interpretativos usados por alunos do ensino secundário*. PhD thesis, Universidade de Aveiro.

Ogborn, J. (1985). Understanding students' understandings. *European Journal of Science Education*, 7(2), 141-150.

Pereira, M. et all, (1983). *Física - 10º ano*. Lisboa: Edições Nave.

Sá, M., (1987). *10º Ano - Física*. Lisboa: Texto Editora.

Sequeira, M. & Leite, L. (1989a). O raciocínio causal e a mudança conceptual no âmbito da Mecânica. Paper presented to the "2ª Convenção de Psicólogos Portugueses - Conferência Internacional: A Psicologia e os Psicólogos Hoje", Universidade de Lisboa, Lisboa.

Sequeira, M. & Leite, L. (1989). Qualitative versus quantitative physics and the conceptual understanding of Newton's laws. Paper presented to the

"14th Conference of the Association for Teacher Education in Europe", University of Kristianstad, (Sweden).

Sequeira, M., Leite, L. & Duarte, M. C. (1989). Concepções alternativas sobre a queda dos graves: Propostas para uma estratégia de ensino. Poster presented to the "III Congreso Internacional sobre la didáctica de las ciencias y de las matemáticas", Universidade de Santiago de Compostela, (Spain). Published in the Proceedings.

Silva, L. & Valadares, J. (1985). *Manual de Física - 10º ano de escolaridade.* Lisboa: Didáctica Editora.

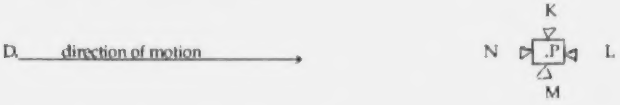
Viennot, L. (1979). *Le raisonnement spontané en dynamique élémentaire.* Paris: Hermann.

APPENDIX 1

THE SPACESHIP PROBLEM

1 - A spaceship with four engines (K, L, M, N) disposed according to picture 1 stands in outer space where there is no friction (no atmosphere) and no gravity.

1.1 - Imagine that the spaceship is moving with constant velocity, and passes by a point D and and after that by a point P (Pict 1).



Pict. 1

1.1.1 - Are any of the engines on when the spaceship moves between points D and P? In case of an afirmative answer, specify which engine(s) is(are)on.

a) In any case, justify your answer.

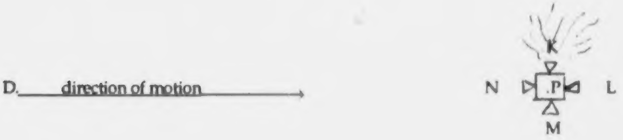
1.1.2 - Is there any force on the spaceship when it passes by point P?

a) Justify your answer.

b) If your answer to question 1.1.2 was "yes", draw, on Pict.1, the force(s) acting on the ship.

1.2 - Immediately after point P engine K is the only engine on, for ten seconds.

1.2.1 - Draw the trajectory taken by the ship during that time. Label the point where the ship will be after the ten seconds by "Q".



Pict. 2

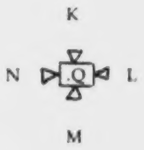
1.2.2 - Describe what happens to the speed of the spaceship between points P and Q.

1.3 - Immediately after point Q engine K is turned off.

1.3.1 - Does the ship stop or does it keep moving?

a) Justify your answer.

1.3.2 - If your answer to question 1.3.1 was "Keeps on moving", draw on Pict 3 the trajectory you think the ship will take; If you answered "It stops", you do not need to make any drawing.



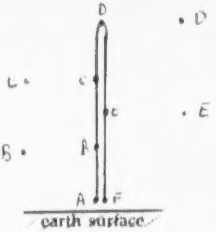
Pict.3

1.4 - In the box below, draw the complete trajectory of the ship and mark points P and Q. Remember that: The spaceship moves with constant velocity between points D and P; Between points P and Q engine K is the only engine on; Just after point Q engine K is turned off.

Pict. 4

THE COIN TOSS PROBLEM

1 - Picture 1 shows the trajectory of a coin thrown up vertically into the air, leaving the hand at point A, reaching a maximum point D, falling down vertically, and being caught at point F. Air resistance is to be ignored.



Pict.1

1. 1 - **Draw, at the points placed laterally, the force(s) that act on the coin when it is at points B, C, D and E. Label the force(s) represented.**

1.2 - Describe the reasoning done to answer to the previous question.

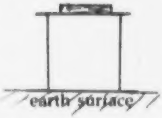
1.3 - **Describe what happens to the velocity of the coin:**

1.3.1 - **during the ascent.**

1.3.2 - **during the descent.**

THE BOOK ON TABLE PROBLEM

1- Picture 1 shows a book at rest on a table.



Pict.1

1.1 - Is(are) there any force(s) acting on the book?
___ No
___Yes

If you answered "No", justify your answer.

If you answered "Yes", draw the force(s) on Pict.1 and label them.

THE TWO SPHERES PROBLEM

1 - Imagine two massive equal size spheres, one made out of iron and the other made out of wood.

1.1.a - Compare the falling time of the two spheres, when they are released from the same level, in the air.

1.1.b - Describe your reasoning.

1.2.a - What would happen if the two spheres were released from the same level in a vacuum tube (tube without air)?

1.2.b - Describe your reasoning.

COGNITIVE STYLE OF STUDENTS AS AN ESSENTIAL FACTOR OF FORMING THEIR PHYSICAL WORLD CONCEPTION

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Speaking about the objectives of teaching physics, we might as well start from B.S. Bloom's a by today classical taxonomy of educational objectives that distinguishes between two principally different levels. Confining ourselves to the first one, the level of knowledge, would make the further discussion irrelevant, since on that level physics or whatever other subject can be aquired by any student. The question is simply how much labour for that purpose is utilized. In the long run, the entire didactics for gaining that aim recedes to the principle: Beat a rabbit long enough and it will learn to stike a match. Unfortunately, one has to admit that such an approach is rather a widely spread one, as it is the greatest pleasure of a lecturer to listen to his or her own words from the mouth of a student. However, if we start from the higher levels of objectives, try to align the student's physical knowledge with his or her general world conception and form an integral system of physigcal knowledge, we cannot avoid comprehension as the basis of higher educational objectives. Comprehension in its turn, presumes taking into consideration the individual and personal peculiarities of a student. It is undoubtedly clear that what is not known cannot be understood, and it is much easier to remember comprehensible material than try to learn by heart something one does not understand. Comprehension can be observed as a compound unit of the student's structures of knowledge and stimulus, and in this interaction of two components neither of them should be underestimated.

In educational research, the individual and personal peculiarities of a student have been observed proceeding from various different conceptions. The majority of those conceptions, however, have rather an unpleasant quality in common - they are estimative. There exist certain qualitis, the possession of which is "good", and the others, the possession of which is considered "bad". Applying that scale of estimation to students, we group them as good or bad ones and such a classification will lead us nowhere. Interesting, although little used is an approach found in present day American personality psychology - the approach through cognitive styles. This trend examines the problem proceeding from the standpoint of structure abstracted from the content. The trend was launched in the '40s by Adorno, Frenkel-Brunswik et al. with the research on authority. Up to now the research has progressed in the direction of observing abstraction from the content and the structure of cognition. In some sense, the basis of this research trend can be taken as a continuation of Freud's ego-psychology. While "ego" to Freud was an intermediary between "super-ego" and "id", the ground for the trend in question is defining cognitive process as an intermediary process between environmental influence and organism reaction to it. Arising from that definition, cognitive style expresses certain structural qualities of cognition that are relatively constant. Goldstein and Blackman, in their monograph describe cognitive style as the term which refers to the characteristic ways in which individuals conceptually organize the environment (Goldstein, K.M., Blackman, S. 1978). H.Witkin et al. claim that in the case of cognitive styles "we were dealing with a broad dimension of individual differences that extends across both perceptual and intellectual activities" (Witkin, H.A. et al. 1977). They enumerated the essential characteristics of cognitive styles in general: First, cognitive styles are concerned with the form rather than the content of cognitive activity. They express differences in how people perceive, think, solve problems, communicate with others, etc. The definition of cognitive styles is thus cast in process terms.

Second, cognitive styles are pervasive dimensions. They pervade the spheres of human psyche that have usually been isolated and thus help restore the holistic state characteristic of psyche. The given quality becomes well apparent in educational context. Reflecting their pervasiveness, cognitive styles carry that something what is usually called a personality. Thus, they are not only the qualities of cognition in the narrow sense, but also the qualities of an individuum. The pervasiveness of cognitive styles also means that they can be estimated with non-verbal methods. In the range where perception can be measured with objective means, perceptive activity may be used as a measurable "tracer" to determine the cognitive style of an individuum.

A third characteristic of cognitive styles is that they are stable over time. It does not mean that they are unalterable, some of them are altered very easily. In the normal course of events it is, with certain exactness, possible to assume that a person possessing a certain style on one day possesses the same style on the other day, in the other month or even year. Such a stability makes it possible to partly use stylistic dimensions in long term advices and supervisions. The constancy of cognitive styles is also proved by the H.Witkin research group that carried out a long-term experiment (Witkin, H.A. et al. 1967), where it became clear that certain shifts in cognitive styles can be observed with persons between the ages 8-17; between 17-24 no essential changes in cognitive styles were evident.

Fourth, with regard to value judgements, cognitive styles are bipolar. This quality has a special importance in distinquishing cognitive styles from intelligence and other ability characteristics. In the sense of evaluation, abilities are unipolar i.e. possessing more abilities is better than possessing them less. In the case of cognitive styles, however all poles have an adaptive value in certain conditions and in these conditions, i.e. in concrete situation, can have a positive evaluation.

The empirical investigations of cognitive styles (Kolga, V. 1984) show us that cognitive styles are described simultaneously as characteristics of individuum and personality. On one hand, we have to deal with ontogenetic priority and even genetic determination of cognitive style. On the other hand, cross-cultural studies of cognitive styles show us that individuals develop a cognitive style which is encouraged in their culture and which is adaptive to their habitat. Family, child-rearing style and education are powerful factors in cognitive style formation.

Adopting the standpoint of H.A. Witkin and his colleagues (Witkin, H.A. et al. 1977), according to which cognitive style is observed as a source of continuity of perception and behaviour, we come up against a new problem. The problem results from the circumstance that the dimensions of cognitive styles are closely connected with the corresponding tests and derive directly from laboratory investigations. Different sources (e.g. Petzoldt, M. 1985) describe up to nineteen different dimensions of cognitive styles and bringing them all under one denominator, at first causes a lot of bewilderment, and, what is more, no genarally accepted and theoretically argumented system has been created, as yet. With several dimensions of cognitive styles, the validity of the characteristics mentioned in literature falls under suspicion, and the only uniting link between the dimensions is their aiming at the structure of perception. As much as the empirical evaluation of the effectiveness of utilization of the given nineteen cognitive styles is obviously beyond our strength, we have to proceed from the existing research works dealing with educational implications of cognitive styles (Clauss, G. 1984, Wagner, J. 1978). Basically two dimensions of cognitive style are observed by teachers: reflection - impulsivity and field dependence - field independence. Analysis shows us that those dimensions have an essential impact on teaching physics, as well, since they are closely connected with material comprehension.

In the case of field dependence - independence dimension of cognitive style, we have to deal with a quantitative characteristic that illustrates the extent up to which the surrounding organized field influences the perception of the surrounded phenomenom (Witkin, H.A. et al. 1977); the extent up to which the given person perceives the discrete part of the field in surrounding integral field, or the extent up to which the organization of the prevailing field is determined by the perceptiveness of its components. In everyday speech, it means the extent up to which a person is capable of perceiving analytically. One pole of the scale of perceptive activity is strictly determined by the prevailing field and it is called "field dependent", as to the other pole the, subject experiences the phenomenom present in the field more or less separately from the field. This pole is called "field independent". Field independence has been defined as an ability of surpassing disquised connections with the help of perceptive activity, and in the case of a differentiated approach to field perception, it is observed as an analytical aspect of perception as it is expressed in perception. Practically, field dependence - field independence finds its expression in problem solving and reflection connected with symbols. A student who is incapable of separating a phenomenom from its surrounding environment, i.e. is field dependent, has difficulties in solving certain types of problems. In such problems, the solution depends on seperating a certain element from the context and restructuring the material so that the given phenomenom would be presented in new connections. Empirical investigations have shown, that difficulties will arise only in solving certain types of problems. At the same time, the field dependent students are more successful in obtaining social disciplines, it has been observed that the attention of these students is selective towards the social aspects of the environment. So, we have the ground for presuming that one possible source of difficulties in learning physics is the field dependent cognitive style of certain students that is not effective for processing symbolical and strictly structured material. There is also evidence of differences in choosing one's career depending on cognitive style (Witkin, H.A. et al. 1977, Сочивко, Д.Б. 1986). Students with field - independent cognitive style prefer mathematics, sciences, architecture. It is pointed out as well that a teacher with certain cognitive style prefers a student with the cognitive style nearer to his or hers. This gives ground to another possible source of difficulty, namely the field independent teacher of physics attempts to teach the students according to his or her strategy of acquiring the material. This, however, may not be acceptable to a field dependent student.

The difference in the quality of learning and also perceptive activity in general has often been motivated starting from the presumption that one student is more interested in the results of his or her work than the other, or, that one has more knowledge concerning the task then the other. Although the above mentioned reassons undoubtedly exist, there are other cognitive processes involved in problem solving as well. One of those processes expresses the extent up to which a student is able to reflect the adequacy of the hypothesis of the solution. Some students choose hypothesis quickly with only a minimum analysis of their probable exactness. Others, students with the same level of intelligence, spend considerably more time on finding the right solution. The first group is called impulsive and the second reflective students (Kagan, J. 1966). Impulsive persons solve test tasks quickly. When the difficulty level of a task increases, the time spend on solving does not practically change, while the number of mistakes made increases abruptly. Reflective persons solve the tasks more slowly than the impulsive ones. Even with simple tasks, they check a number of different hypothesis before making a final decision. With the growth of difficulty level, the number of mistakes made by reflective persons is not considerably bigger, but the time spent on finding a solution grows substantially. The tendency to behave either impulsively or reflectively has proved to be individually steady. Although, at a certain age children tend to lose impulsivity, a relative place in one's age group is generally preserved.

Reflection - impulsivity expresses a tendency to reflect over solutions in the conditions where it is possible to choose between a number of alternatives and there exists a certain indefinitness for choosing the best alternative (Messer, S.B. 1976). Generaly there exists a ruling standpoint that reflective students are, at a certain difficulty level, much more adequate in considering the requests of a task than the impulsive ones. With very simple tasks, reflectivity hinders students more than helps them.

As regards learning physics concretely, the most critical factor with the reflection - impulsivity dimension of cognitive style is material abstractness. Analysing works concerned with text readability (e.g. Klare, G.R. 1969, Groeben, N. 1982), it becomes apparent that abstractness is an essential factor in determining text readability and comprehension. When in processing concrete material, it is possible to react to it impulsively, then a highly abstract text needs a deeper reflection for comprehension, deeper than is within the powers of an impulsive student.

Hence, there is ground to maintain that one of the probable sources of difficulties in teaching physics is the cognitive style of a student (Томуск, В.Б. 1990). Information processing strategies peculiar to impulsive and field dependent students are incapable of grasping the material that is strictly structured, highly abstract or symbolyc. At the moment, we have to deal only with a hypothesis that is based on theoretical treatment and empirical investigations of cognitive styles. Works that would be concretely devoted to connections between the structure and abstractness of study material and material comprehension proceeding from a students cognitive style, have unfortunately not reached us. The problem seems to be highly enchanting, already for its practical side only, since the aim of today's education cannot be a compulsory cramming of a certain amount of facts that would be hopelessly outdated in some years, but forming an integral and evolving world conception. It presumes, however, comprehension of the material and uniting it to a cognitive integrity. We have an experiment under preparation that is concerned with the practical investigation of the above mentioned connections. As the estimation of a student's world conception is beyond our strength, we try to find connections between comprehending a text compiled according to certain criteria and the cognitive style of a student. The next step should be compiling concrete methodical instructions for presenting study material to students with different cognitive styles. As we cannot present any concrete plan for teaching physics at the moment, we could offer a standpoint proceeding from the above discussion: a student who has poor results in learning physics, may not be so foolish or laizy. His or her world has been constructed a bit differently and the physics we offer does not fit into that world. We cannot accuse the student for that and learning physics is not an objective in itself.

References

Bloom, B.S. Taxonomy of Educational Objectives. Handbook I. New-York, 1967.

Clauss, G. Differentielle Lernpsychologie. Eine Einführung. Berlin, 1984.

Goldstein, K.M., Blackman, S. Cognitive Style: five approachis and relevant research. New-York, 1978.

Groeben, N. Leserpsychologie: Textverständnis - Textverständlichkeit. Aschendorf, Münster Westfalen, 1982.

Kagan, J. Reflektion - Impulsivity: The Generality and Dynamics of Conceptual Tempo. Journal of Abnormal Psychology, 1966, 71, 17-24.

Klare, G.R. The Measurement of Readability. Ames, Iowa, 1969.

Koiga, V. Kognitiivsed stiilid isikuslike ressursside süsteemis (Cognitive Styles in the System of Personality Resources). In T. Tulva (Ed.), Õppimiseelduste kujunemine ja koolivalmidus. Tallinn, 1984.

Messer, S.B. Reflection - Impulsivity: A Review. Psychological Bulletin, 1976, 53, 1026-1052.

Petzoldt, M. Kognitive Stile. Psycol., Erz., Unterr., 1985, 32, 161-167.

Сочивко, Д.Б. К вопросу о соотношения научных интересов и индивидуальных стилей познавательной деятельности у студентов. В сб.: Когнитивные стили. Таллинн, 1986.

Томуск, В.Ю. Когнитивный стиль ученика - будущего инженера как важный фактор понимания научно-технического текста. In print.

Wagner, J. Wahrnemung und Kognitive Stile. K.J. Klauer (Hrsg), Handbuch der Pädagogische Psychologie. Band 2, Düsseldorf, 1978.

Witkin, H.A., Goodenough, D.R., Karp, S.A. Stability of Cognitive Styles from Childhood to Young Adulthood. Journal of Personality and Social Psychology, 1967, 7, 291-300.

Witkin, H.A., Moore, C.A., Goodenough, D.R., Cox, P.W. Field-Dependent and Field-Independent Cognitive Styles and Their Educational Implications. Journal of Educational Reseearch, 1977, 47, 1-64.

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